THE BEAMA JOURNAL

AUGUST 1959

A feature of the BEAMA electrical exhibit at the 1959 Rand Easter Show

A QUARTERLY REVIEW OF

BRITISH ELECTRICAL AND ALLIED ENGINEERING

Special Feature in this issue: Welding

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Volume 66 : Number 3 : August 1959

The BEAMA Directorate

MR STANLEY F. STEWARD, CBE, who was appointed Director-Designate of the British Electrical and Allied Manufacturers' Association in February of this year, assumed executive responsibility as Director of the BEAMA on August 1.

Mr Steward has had a wide experience of the industry from many different aspects, having been Director-General of Machine Tools in the Ministry of Supply; the first Chairman of the South Western Electricity Board on the nationalization of the electricity supply industry, and Chairman of the Lancashire Dynamo Group of companies until he joined BEAMA in February last.

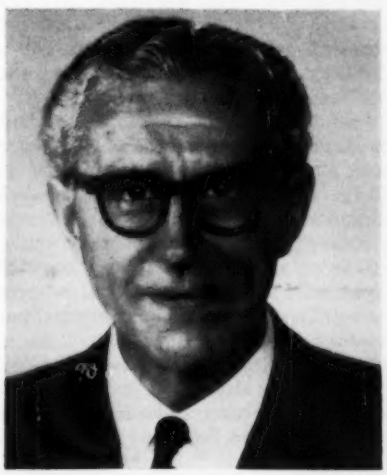
Colonel B. H. Leeson, CBE, TD, MIEE, relinquished his position as Director of the BEAMA on July 31, but his services will continue to be available to the BEAMA in a consultative capacity until his retirement in 1960.

Colonel Leeson, who has been the Director of the BEAMA since 1946, has had a distinguished career in the electrical industry, and was previously the managing director of A. Reyrolle & Co Ltd. He is President of the British National Committee of the International Electro-Technical Commission, Chairman of the Board of Governors of Faraday House, and Chairman of the Association of Short-Circuit Testing Authorities (ASTA). He was President of the Institution of Electrical Engineers in 1952–53.

Mr D. Maxwell Buist, MIEE, MIEX, Export Director of the BEAMA, will also be retiring in April 1960, when he reaches normal retiring age. He will, however, relinquish his full-time executive responsibilities in October this year, and for the ensuing six months will act in a consultative capacity.

Mr Buist's services to the electrical industry during his twenty-two years with the BEAMA are well known both in the UK and overseas. Before joining the Association he was with the Central Electricity Board as Manager, North-East England, and before that was Chief Electrical Engineer, Imperial Chemical Industries Ltd at Billingham. He was Chairman of the Institute of Export from 1951 to 1954; has served on many Government overseas missions, and is a member of numerous committees concerned with the export trade.

(Left)
Mr Stanley F. Steward, CBE



(Right)
Colonel B. H. Leeson, CBE, TD, MIEE

BEAMA President Honoured

The honour of a knighthood was conferred by HM The Queen in the recent Birthday Honours List on Mr Leslie Gamage, MC, MA, Chairman and Managing Director of the General Electric Co Ltd and President of the BEAMA.

Mr Gamage joined the GEC in 1919 as Assistant Secretary. He became Secretary in 1920 and was elected to the Board of Directors in 1925 when he assumed responsibility for the company's export business. He is a firm believer in the importance of industrial executives making personal visits to overseas territories to study at first hand the problems of selling in these markets, and he has himself made frequent and lengthy visits to overseas countries in many parts of the world. These visits have invariably resulted in increased trade and the expansion of the company's overseas organization.

For several years Mr Gamage has been Chief Business Adviser to the Ministry of Transport and Civil Aviation. He has been a member of the Grand Council of the Federation of British Industries for the past twenty-six years and for twelve years served on the Council of Industrial Design. From 1942 to 1957 he was President of the Institute of Export.

Our Special Features

This issue contains the first of a series of special features and thus inaugurates a new policy of including in each issue of THE BEAMA JOURNAL a feature devoted to a specific field of electrical engineering practice. These features are designed to present to potential buyers and users overseas an authoritative and balanced review of the latest British achievements, techniques, and equipment in the fields to be covered.

The subject of the special feature in this issue is welding, and its various aspects and applications, including non-destructive testing, are discussed in articles by specialist contributors. There is also a detailed review of the exhibits of BEAMA member-firms at the recent Engineering, Marine, Welding, and Nuclear Energy Exhibition in which special reference has naturally been made to the exhibits in the Welding Section of the exhibition.

The importance of the contribution which welding is making to the engineering industry as a whole is growing year by year, and the development of new techniques, and particularly the extension of automatic processes and electronically-controlled equipments, will add increasing emphasis to the vital rôle of welding in many widely diverse fields of fabrication.

Considerable interest has recently been focused on the welding of the pressure vessels of the reactors for the new nuclear power stations. Increasing gas pressures have called for increasing thickness of the shells—from 2 in (50·8 mm) at Calder Hall to 3 in (76·2 mm) at the stations now building, and the challenge of welding these great structures on site has been most successfully met by the constructional firms concerned and by the manufacturers of the welding equipment, and especially of arc welding electrodes.

The very high standards of welding required for this critical work have also put fresh emphasis on techniques of non-destructive testing, and an article reviewing the latest developments in this field is a logical inclusion in a survey of welding practice.

Pressure vessel welding is, however, only one of the many newer welding developments; other important (even if less spectacular) examples are to be found in the fields of shipbuilding, aircraft production, and automobile construction. The progress in developing new automatic welding processes is opening up new fields in the shipyards and will undoubtedly lead to an increase in the amount of welding which is done automatically—at present estimated at between 10 and 15 per cent.

The Victor Crescent V-bomber—one of Britain's first-line aircraft and the world's largest aeroplane to have exceeded sonic speed on a routine test flight—incorporates some 550,000 spot and roll-spot welds in its construction.

An all-welded under-frame, doors, and other components produced at the rate of up to 120 assemblies an hour on fully automatic production lines are features of one of Britain's biggest selling motor-cars.

We could quote many other notable examples of the lead which British welding manufacturers have established in a wide field of applications, and the contents of our special feature are eloquent testimony to the progressive outlook of this important section of the British electrical industry.

The features provisionally scheduled for subsequent issues of THE BEAMA JOURNAL are:

1959	
November	Industrial Heating—including arc and resistance furnaces, RF and dielectric heating.
1960	
February	Industrial Power: motors, contactors, switchgear; control systems; automation.
May	Rectification: rotary converters, mercury arc rectifiers; semi-conductors.
August	Electric Traction.

The BEAMA Journal—An Explanation

Publication of this issue has been unavoidably delayed by circumstances outside our control. This has also prevented us from producing a slightly larger issue than usual, as we had planned to do in order to include the special articles on welding, as well as a full report of the Engineering, Marine, Welding, and Nuclear Energy Exhibition. We regret that we have therefore been compelled to curtail some of the regular editorial features.

The November issue will be published as usual.

Cover illustration. *The specially commissioned portrait bust of Faraday which, with similar busts of Watt and Rutherford, was a prominent feature of the collective exhibit organized by the BEAMA Southern African Overseas Committee at the 1959 Rand Easter Show. The busts and the related models of equipment have now been presented to the University of Witwatersrand.* (*See* '*Gold Medal for BEAMA Exhibit*' *on page 104.*)

Recent Nuclear Developments

THE first nuclear power station in Scotland at Chapelcross, near Annan in Dumfriesshire, was officially opened on May 2. It had actually started generating electricity on February 25, about a week ahead of the scheduled date and only three years after construction work began on the site.

Chapelcross had its origin in June 1955, when increased supplies of military plutonium were urgently required and it was decided to build three new units of the Calder Hall type, each consisting of two reactors and the necessary ancillary equipment for electricity generation. One was to be sited alongside the first Calder Hall station; the other two were to be at Chapelcross.

With No 1 reactor now in operation, work is going ahead on the other three reactors and they are due to be commissioned at intervals during the remainder of this year. When completed, Chapelcross will have a maximum electrical output of 184 MW and a net output of 140 MW.

As Chapelcross is about 75 miles (120 km) from the plutonium factory at Windscale, it has been necessary to provide a water-filled storage pond for the irradiated uranium with a capacity sufficient to hold fuel cartridges equivalent to about three reactor charges. As the Chapelcross reactors can be refuelled only when they are shut down, refuelling time must be kept to a minimum. Here the storage pond helps by making refuelling almost entirely independent of external transport arrangements.

A recent design modification to Nos 2, 3, and 4 reactors is the introduction of removable graphite sleeves in all fuel channels to provide a solution to the stored energy problems associated with irradiation damage of the graphite moderator, generally known as the Wigner effect. As it is not possible to raise the gas inlet temperature above the design figure of 140 deg C, an alternative solution is the provision of removable sleeves designed to leave a small gap between them and the bulk of the graphite. This gap becomes filled with the coolant gas and acts as a thermal insulation barrier, ensuring that the bulk graphite temperature is raised above its normal value to provide some measure of self-annealing.

The 'Zenith' and 'Dragon' Reactors

Further details can now be given of the Zenith and Dragon reactors, mentioned briefly in our last issue, which form part of the programme at the AEA's newest research establishment at Winfrith Heath in Dorset.

The main function of this establishment is to initiate basic research and early development work on all aspects of atomic energy and in particular to provide new ideas and basic design data for application to power generation. The first projects to be undertaken—Zenith and Dragon—are concerned with the high temperature gas-cooled reactor (HTGR) which is expected to provide the basis of the third generation of nuclear power stations.

Zenith, which has been built by the General Electric Co Ltd and is expected to go critical later this year, is a zero energy reactor built to operate under temperature conditions similar to those which will be encountered in a high temperature power reactor.

Zenith has a core diameter of approximately 4 feet (122 cm) comprising 235 fuel elements, each consisting of a finned graphite sleeve containing pellets of uranium oxide, thorium oxide, and graphite. The ends of the fuel elements are of solid graphite, and together with a 3 ft (91 cm) thick graphite annulus surrounding the core they form a reflector to return some of the escaping neutrons into the core, so reducing the quantity of fuel used.

Nitrogen gas, heated by a 250 kW heater, is circulated through the core to raise it to a temperature of 800 deg C. The reactor itself will be operated at a maximum nuclear power of 100 W—sufficient for the nuclear physics measurements, but low enough to avoid inducing such high activities in the fuel that rearrangement of the core would be difficult to carry out.

Zenith is also closely allied to 'Dragon', which is the OEEC High Temperature Reactor project in which twelve OEEC countries are participating. Six of them—Belgium, France, Italy, Luxembourg, the Netherlands, and Western Germany—will participate through Euratom; the other partners in the enterprise are Austria, Denmark, Norway, Sweden, Switzerland, and the United Kingdom. The headquarters of the project, which covers a period of five years, are at Winfrith, where the 10 MW Dragon reactor will be built and operated by a team of scientists from the participating countries.

High-Energy Generator at AWRE

Recently the press were allowed for the first time to visit the Atomic Weapons Research Establishment (AWRE) at Aldermaston in Berkshire, to see some of the work of the Nuclear Physics Research Division which was formed some four years ago. The initial purpose of the Division was to obtain certain technical data required for the atomic weapons project, and it was necessary to set up several machines for achieving nuclear transmutations and for following nuclear reactions in fine detail.

Of the four nuclear machines in use at Aldermaston, the new 12 MeV tandem electrostatic generator will make it possible to extend the survey of nuclear elements to much higher energies and thus to explore heavier nuclei. Designed by AWRE in collaboration with the Atomic Energy Research Establishment at Harwell and with Metropolitan-Vickers Electrical Co Ltd, the machine is a modification of the electrostatic generator and provides the great advantage of obtaining microampere beams of charged particles with a controllable energy of 12 MeV while applying an electrical potential of only 6 MeV. Such energies have hitherto been attainable only in cyclotrons, the energy of which cannot easily be varied. Another advantage is that, since the ion source is at earth potential, it can be built outside the tube and can thus be made on a much more elaborate scale than that of the orthodox Van de Graaff accelerator.

Other machines at Aldermaston include a 6 MeV and a 3 MeV electrostatic generator, and an 800 keV Cockcroft-Walton machine.

A Survey of Some Recent Developments in Arc Welding

*E. Flintham**

ALTHOUGH the use of arc welding has expanded over the past twenty years at an exceptionally rapid rate, it has accelerated more recently because of the pressure of two main factors: first, the necessity to join both existing and new materials of construction to ever-rising quality standards, encountered typically in the nuclear power and petroleum industries; second, the need to increase productivity to offset the impact of increasing and keener competition.

At first sight it would seem that a multiplicity of welding processes is available, some of which appear to duplicate or at least overlap the functions of others. This is, however, a superficial impression; each process has different advantages to offer, and it becomes a question of selecting that process which shows the maximum advantage and suitability for a particular application.

MANUAL METAL-ARC WELDING

By far the most important arc welding process is still manual metal-arc, both in the extent of its usage and its versatility of application. Its application to weldable ferrous metals and alloys is bounded only by the practical difficulty of welding very thin material. In considering the manual metal-arc process, one sees growth in present applications rather than the advent of entirely novel applications, although there have been new developments in both electrodes and equipment which have made important contributions towards the expansion of the process.

Electrodes

Two of the most important developments in the manual electrode field in the last decade are the low hydrogen electrodes and the electrodes containing iron powder. The use of low hydrogen electrodes has widened the field of application generally, making it possible to weld difficult alloy steels with ferritic electrodes, and giving a greater assurance of safety in fabricating mild steel where heavy sections are used or a severe degree of restraint is inherent in the construction. The nature of the basic type of covering for such electrodes produces a very fine-grained ductile weld metal, with high notch-toughness and a very low gas content. Other advantages of low hydrogen electrodes are their tolerance to sulphur-rich steels of free-cutting quality, and their suitability for welding medium-high tensile and low alloy steels for work exposed to low temperature service conditions, or where high radiographic standards are demanded. They can also be used for fabrications requiring subsequent enamelling or glass-lining, since the low gas content of the weld metal prevents 'blistering'.

The atomic energy industry has demanded electrodes with exceptionally good low-temperature impact properties for the welding of thick plates in reactor vessels. High quality electrodes have now been produced combining first-class weldability in all positions with the requisite impact properties and radiographic standard.

In step with the demand for high productivity in manual welding, electrodes have been introduced with heavier coverings containing varying proportions of free iron powder, in order to speed up deposition rates. The increased speeds of welding attainable can lead to very considerable cost savings. The ease of welding and slag removal, the neat appearance of the welds, and the high welding speeds are all attractive features of the latest iron-powder-containing electrodes.

One of the most interesting of recent developments is an iron-powder-containing electrode with a rutile covering depositing weld metal with a low diffusible hydrogen content—a feature hitherto only associated with basic-covered electrodes. This type, classified as E.9xx in the BS 1719: 1952 coding system, couples the metallurgical advantages of the fully-basic E.6xx class with the attractive and easy operational advantages characteristic of the Class 2xx rutile types. In addition to easy running and de-slagging, these electrodes can also be used in all positions. Furthermore, they have the great economic and metallurgical advantages that particularly high currents can be used to obtain maximum speeds of deposition without the usual sacrifice in mechanical properties of the weld metal which occurs when exceptionally high currents are used with conventional rutile electrodes.

Fig 1. A portable oil-cooled rectifier welding equipment designed for ac or dc supply

Equipment

The most notable advance in the provision of equipment for manual metal-arc welding has been the introduction of metal rectifier plant. Where dc plant is required or is preferred because of the unbalanced mains loading caused by the operation of single-phase ac transformer equip-

* Sales Manager, Quasi-Arc Limited.

ment, the rectifier offers many advantages over rotary sets.

Two types of rectifier are available. Selenium rectifiers have been in use in this country for some six years, during which period they have shown extreme reliability and excellent welding performance, as well as being easily maintained and having a high electrical efficiency. More recently the silicon rectifier has also been introduced. It has an even higher electrical efficiency than selenium, and since the plates are completely sealed it is particularly suitable for use in chemically corrosive atmospheres. The elements are extremely small both in dimensions and thermal capacity, and thus may be damaged by the overload currents and voltage surges which are common in arc welding performance. This shortcoming can be overcome by providing sufficient rectifier capacity to meet the most arduous conditions.

Welding plants providing either an ac or a dc welding supply are now available. This oil-cooled equipment (Fig 1) consists of a transformer with regulator, silicon rectifiers and ancillary gear, all contained within one compact unit. The operator is able to select the required type of supply, ac or dc positive or negative, by means of a simple three-position switch and current control is provided by tapping switches, all mounted on top of the plant.

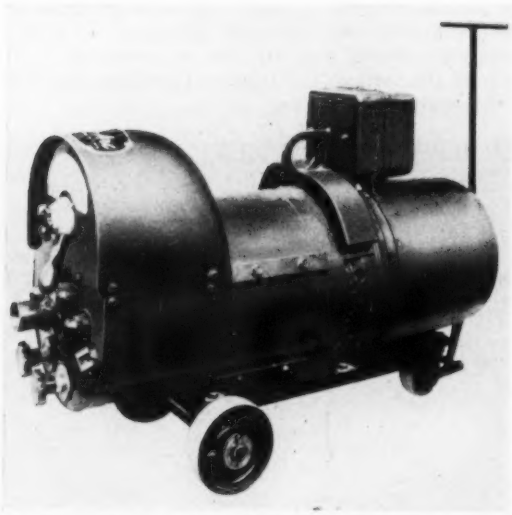


Fig 2. The small dimensions of a new 225 A motor generator welding set can be gathered from this photograph

Where users already operate ac welding plant, a need often arises, principally when light alloys or non-ferrous materials are to be fabricated, for an additional dc supply. Conversion equipment is now available in the form of the 'plug-in' type of rectifier, consisting of an air-cooled single-phase silicon rectifier unit and choke. This can be used with a 300 A ac transformer plant, with an open circuit voltage of 80/100, under which conditions a maximum welding current of 250 A dc is alternatively at the disposal of the user. The main feature is that the equipment is completely static and installed simply by plug-in leads to the existing machine.

The use of a high speed generator operating at 3000 rpm with a specially designed cooling fan has made it possible to introduce engine-driven and motor-driven generator welding plants which are cheaper and physically smaller than the normal types working at approximately half that speed. The small dimensions of a 225 A output motor generator plant using this new principle are illustrated in Fig 2.

Fig 3. Semi-automatic welding of aluminium using the argon-shielded bare wire process

SEMI-AUTOMATIC WELDING

There is intense interest in the possibility of providing satisfactory methods of semi-automatic welding. Considerable progress has been made with equipment using the gas-shielded bare wire process, particularly in the welding of aluminium and its alloys. Equipment for using thinner wires than hitherto has been introduced and this will extend the field of application to include the welding of light gauge materials and also the positional welding of steel. Recent developments of semi-automatic processes include the use of carbon dioxide gas shielding with a continuous tubular electrode formed from strip enclosing flux ingredients; the use of bare wire with fluxing ingredients entrained in a shielding gas or with magnetic flux, and the use of a continuous covered electrode with or without a shielding gas.

Gas-shielded Bare Wire Process

As its name implies, this process employs a wire electrode shielded by an inert gas such as argon, argon-oxygen mixtures, carbon dioxide, or in some cases nitrogen, depending on the material to be welded. The main advantages of the process are its speed compared with manual metal-arc welding and its usefulness in applications where a slag cover is undesirable or de-slagging is difficult or impossible.

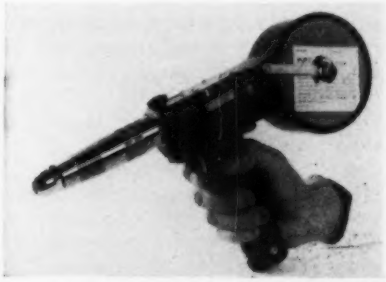


Fig 4. A welding gun incorporating a 'puller' wire feed unit for thin-wire welding

Originally developed for the fluxless welding of aluminium and its alloys, it has since been used for aluminium bronze, stainless steel, copper and mild steel fabrication, and is finding many applications in the chemical, oil, general engineering, and shipbuilding industries. The process is now being used, for example, in the manufacture

of chemical and food processing vessels, road transport fabrications, storage tanks, and ships' superstructures.

The most spectacular success to date is still its original application to the welding of aluminium alloys, using argon shielding (Fig 3); welding speeds are much higher than those obtained with the non-consumable tungsten electrode process or with manual covered electrodes. Moreover, a wider range of alloys is weldable than with manual electrodes, and the necessity for the careful removal of corrosive fluxes is eliminated. Positional welding is also rendered very much easier.

The development of the application of the process, using carbon dioxide gas shielding, for the welding of mild steel appears to be more promising now that power sources with improved characteristics have become available, *e.g.* dc welding plants having arrangements for slope control or the incorporation of reactance. Such devices increase the arc stability and also reduce the amount of spatter, thus improving the standard of welding.

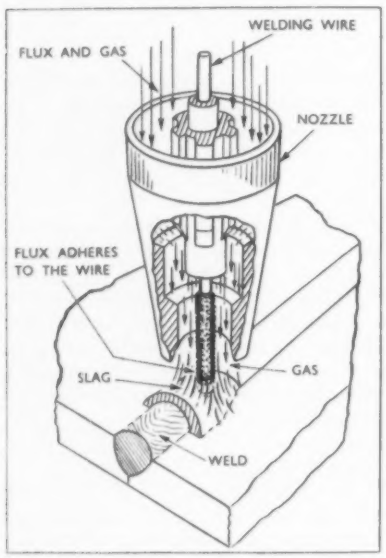


Fig 5. Diagram illustrating the principle of the gas-shielded bare wire process using a magnetic flux powder

Thin Wire Welding

Until recently, limitations of the gas-shielded bare wire process have been its unsuitability for welding light gauge materials and for welding steel in the vertical and overhead positions. Normally, high current densities are used so as to obtain a self-adjusting arc characteristic, and as a result a deeply penetrating arc has been a feature which made the process unsuitable for welding thin material. By the use of welding plants having special characteristics, lower current densities can be employed and the penetration is considerably reduced.

Another difficulty in trying to weld thin materials with this process has been the difficulty in feeding the thin welding wire required. This has been overcome by the use of a welding gun incorporating a wire feed unit so that the wire is 'pulled' rather than 'pushed' through the welding gun (Fig 4). With this equipment aluminium alloy wire of 0·030 in (0·762 mm) diameter and steel wire of 0·020 in (0·508 mm) diameter can be utilized to weld sheet material as thin as 16 gauge (1·626 mm) in aluminium or 18 gauge (1·219 mm) in steel.

With this process it is possible to make satisfactory welds in steel in all positions, whereas previously welding in positions other than the flat and horizontal-vertical positions, except in the case of aluminium alloys, was not possible.

Gas-shielded Tubular Electrode Process

This new development, using a continuous tubular electrode (with or without an internal reinforcement), fed through a welding gun, has a number of distinct advantages. The electrode contains ionising and deoxidising agents and the slag-forming materials, while the carbon dioxide gas shield gives additional protection to the weld metal during deposition. Extremely high current densities can be employed, giving very deep penetration and deposition rates of up to 22 lb (9·979 kg) of weld metal an hour without any loss in the quality of the weld metal. The process can be used for welding in the flat and horizontal-vertical positions with either ac or dc power sources.

Gas-shielded Bare Wire Process with Added Fluxes

In this process, used for the welding of steel, a mild steel wire is fed through a welding gun where a powdered flux is added to the wire and the arc is additionally shielded by carbon dioxide gas. In one version of the process a magnetic powder is attracted to the bare wire, and in another version a magnetized powder is entrained in the carbon dioxide gas stream. The principle of operation of this process is shown in Fig 5. This method produces in effect a flux-covered electrode protected by a carbon dioxide gas shield, and with this it is possible to make welds in the vertical and overhead positions in addition to the downhand position.

Fig 6. The delivery side of a machine for fully automatic welding with a carbon dioxide shielded bare wire electrode

FULLY AUTOMATIC ARC WELDING

The greatly increased speed of welding possible by automatic methods is the principal though by no means the only attractive feature. In automatic welding, two very variable factors in manual metal-arc welding—arc length and welding speed—are controlled, and this control is the vital factor in achieving high quality welds. In manual metal-arc welding the arc length is entirely dependent on the skill of the operator and can never be precisely constant. In automatic welding the rate of feed of the electrode is synchronised with the actual burn-off rate of the electrode at the arc and thus a constant arc length is maintained.

The two principal automatic welding processes are the open-arc process and the submerged-arc process. Both are about equal in usage in this country; the former with a continuous covered electrode is used more in shipyards and on open sites, and the latter finds its main usages in shop work. Developments in equipment for the open-arc process have been introduced in which carbon dioxide gas shielding is used with bare wire, or with continuous tubular electrode, or with continuous covered electrode, and a method for vertical welding using the submerged-arc process has been introduced.

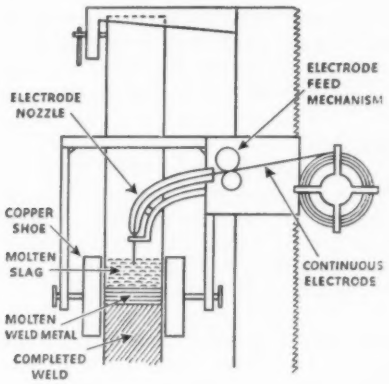


Fig 7. Schematic diagram of the vertical submerged-arc welding process ('electro-slag' welding)

Gas-shielded Bare Wire Process

Basically, the equipment for steel welding consists of a mechanised welding head which carries the wire at the appropriate feed rate and surrounds the arc with an atmosphere of carbon dioxide gas. The close control of the arc length, made possible by the automatic control equipment, considerably reduces the amount of spatter that is normally expected when welding semi-automatically with bare wire and carbon dioxide gas shield, and with the automatic process welds of high quality are produced (Fig 6).

Equipment is available for the welding of aluminium automatically but in this case argon is used as a shielding gas.

Gas-shielded Tubular Electrode Process

It is expected that the main field for this process will be in the hard-facing of parts or the reclamation of worn parts by automatic welding. The tubular formation of the electrode enables alloying ingredients to be added to the weld metal, giving compositions which are not available in wire form, and the use of a carbon dioxide gas shield gives a protective atmosphere preventing excessive loss of the alloys.

Gas-shielded Continuous Covered Electrode Process

One of the limitations of the well-known open-arc automatic welding processes using continuous covered electrodes has been that they have not been readily applicable to the welding of horizontal-vertical fillet welds. Other undesirable features have been the high spatter loss and the difficulty experienced in detaching the slag formed by the basic type of electrode. The introduction of a new type of electrode, used in conjunction with a carbon dioxide shielding gas, has overcome these drawbacks and this new process combines many of the advantages of the open-arc process with the high operating speeds of the submerged-arc process. There is no doubt that this introduction marks a considerable advance in the sphere of automatic welding, particularly in the application of horizontal-vertical fillet welding.

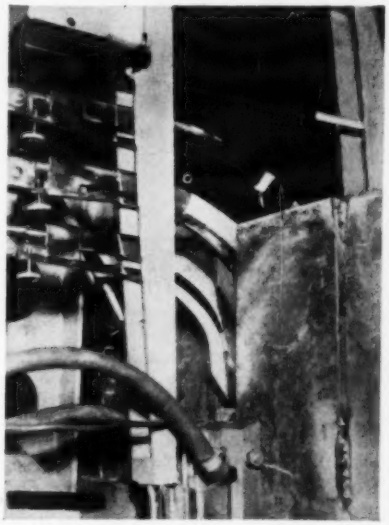


Fig 8. Vertical submerged-arc welding, showing one of the water-cooled copper shoes in contact with the workpiece

Submerged-Arc Process

In the usual application of submerged-arc welding, the electrode wire passes through an over-burden of granular flux powder. The arc operates below this powder and is not visible. Only a portion of the flux powder is fused during welding to form a glass-like slag cover on the weld and the remaining unfused powder is recovered for further use.

Developments in submerged-arc welding are directed mainly towards the achievement of higher welding speeds by the simultaneous use of two or more electrode wires operating in the same weld pool. For some applications the electrodes are connected in parallel to the same power supply, while for other applications the electrodes are each connected to a separate power source with its own arc control system.

Originally limited to welding in the flat position, the submerged-arc process is now applied to the welding of fillets and butts in the horizontal-vertical position and to the welding of butt welds in vertical plates.

The method of welding vertical joints (Fig 7) involves

Fig 9. A 20-ton motorized manipulator arranged to tilt through 135° at fixed speed and rotate at variable speeds

Fig 10. A shipyard installation comprising four automatic welding gantries, two designed for the simultaneous production of twin horizontal-vertical fillet welds, and two for butt welding

some interesting and novel departures from the usual method of submerged-arc welding. The idea originated in Russia as a development known as the 'Electro-Slag' process but variations of the method and equipment, using either a wire or tubular electrode, have also been developed and produced in Great Britain. Very high current densities are used and the welding is done in heavy single passes. By the use of oscillating and multi-electrode techniques, the automatic welding of vertical joints in steel plates up to the maximum thickness commercially available is readily accomplished.

The process is applied to plates set up vertically with a gap of approximately 1 in (25·4 mm) between the square cut edges. Water-cooled copper shoes are held against the plate surfaces and these shoes traverse the joint vertically in step with the welding head. The weld pool and molten slag bath are contained by these shoes and the wire or tubular electrode is fed down through a nozzle into the gap between the plates. The fusion of the plate and electrode occurs under a heavy layer of high temperature electrically-conducting molten slag. The wire or tubular electrode is fed at a constant speed into the weld pool and the gradual and continuous rise in the pool level causes a signal to be given to actuate the automatic lifting mechanism for both the head and the shoes (Fig 8). As the pool of weld metal builds up, the lower part is continuously cooling to form a homogeneous weld with effective fusion of the plate edges and with smooth, clean external faces contoured by the copper shoes.

This method of vertical welding of thick plates has considerable advantages to offer. Only a flame-cut square edge plate preparation is required; transverse or angular distortion is minimised by the even heat distribution through the section, and very high deposition rates can be achieved. The saving in labour costs when welding material more than 3 in (76 mm) thick is very marked and the overall welding time compared with manual metal-arc welding can be cut by as much as 90 per cent.

Specialized Equipment

New developments in welding equipment have evolved as a result of the increasing versatility of the processes described above and particularly with the increasing awareness on the part of industrial users of the potentialities of automatic welding as a cost-saving and time-saving production tool. Simple positioners or mechanized manipulators, designed to enable the welding all to be done in the flat position, considerably improve productivity when using manual metal-arc welding because larger sizes of electrodes and higher welding currents can be used in the flat position than in the other welding positions (Fig 9).

Frequently, the work can be made suitable for welding by standard or special automatic welding heads, either stationary or incorporated in self-propelling machines, often associated with one or more items of manipulating equipment. In many cases, however, requirements are so specialized that the equipment has been designed to fulfil a particular function in the best possible way. An example is to be found in the automatic welding gantry for prefabrication in large shipyards. The machine is designed for the simultaneous production of two horizontal-vertical fillet welds on either side of stiffeners attached to bulkhead and deck panels. The installation basically consists

Fig 11. A self-propelled twin-fillet welding machine for shipyard or general engineering prefabrication

Fig 12. A high-lift swivelling and traversing welding boom for the fabrication of atomic power station pressure vessels

of a gantry spanning the working area and running on rails along the length of the shop (Fig 10). The two welding heads are mounted on a carriage running along the horizontal beam of the gantry and are used simultaneously to perform the fillet welds on both sides of the stiffener. Originally applied to steel welding by the submerged-arc process, machines of this type are now also in use for steel welding by the gas-shielded continuous electrode process and for aluminium welding using the gas-shielded bare wire process.

The success of the gantry installations has awakened an interest in smaller equipments for this purpose where the production demand is not so great. Self-propelled welding machines using the gas-shielded continuous electrode process or the submerged-arc process are now in operation. The machine straddles the stiffener to be welded and, while propelling itself along the length of the stiffener, deposits two fillet welds, one on each side of the base of the stiffener (Fig 11).

The massive fabrications required for the atomic energy industry have called for the use of special equipment. The exceptional size of the vessels and thickness of the plate material have posed special problems in the provision of roller beds to carry the fabrications and high-lift booms for the automatic welding heads (Fig 12).

At the other end of the scale there are ingenious machines designed for the automatic argon-arc welding of thin sheet materials which incorporate a contour-following device by which welded joints of regular or irregular profile can be made without re-positioning the work.

The author acknowledges his indebtedness and wishes to express thanks to his colleagues and other friends who have been helpful to him in the preparation of this article; also to Arc Manufacturing Co Ltd, The English Electric Co Ltd, Metropolitan-Vickers Electrical Co Ltd, Philips Electrical Ltd, Quasi-Arc Ltd, and Rockweld Ltd, for photographs and information provided.

Developments and Techniques in Resistance Welding

*R. W. Ayers**

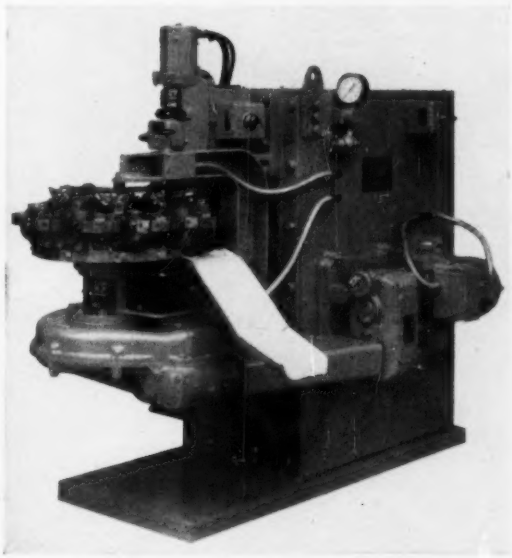
OVER the last fifty years the engineering industry all over the world has been using more and more resistance welding and Britain has played no small part in the development and manufacture of these machines. Progress initially was relatively slow and gained its impetus mainly during and after the second world war. In fact the process is now one of the most important in the engineering field, particularly of course in the sheet metal industry, and its impact has been to influence not only manufacture but design, and in fact many articles now being fabricated by the process could not be made in their present form by any other method, certainly not as economically.

At the present time, when the emphasis is more than ever on productivity involving production of large numbers and economy in their manufacture, it is important that engineers are aware of the progress that has been made in resistance welding and its application. Articles in everyday use such as motor-cars, refrigerators, washing-machines, domestic utensils of all kinds, and wire work in all its shapes and forms, have been influenced to some extent in design, and to a very large extent have become available at prices within the reach of an increasing purchasing public.

Productivity has, in fact, always been the great attraction in the use of this process, but in the early stages complete reliability was not available from the existing machines and the process was not therefore used for highly stressed parts where each weld had to carry its share of the load. When using the larger types of machines there was also the difficulty of the electrical supply available.

Just prior to the last world war great progress was being made in perfecting the control of these machines and therefore the efficiency of the weld, and there can be no doubt that the output from our factories during those critical times would not have been as satisfactory but for the resistance welding process. It is indeed significant that practically the whole of the resistance welding equipment used in those strenuous times was designed and produced in Britain.

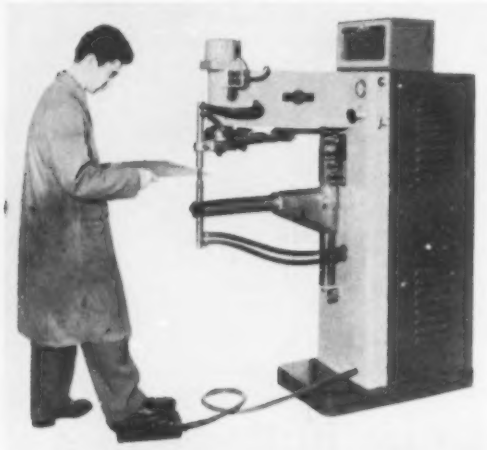
In this country there are a relatively large number of firms engaged in the design and manufacture of resistance welding machines. Competition is therefore comparatively keen, but the result of this competition has been that British machines are comparable with any machines in the world, and in fact in many instances are superior.



Automatic indexing projection welder used in large quantities during the war for welding baseplates to 25 mm shells

* Managing Director, Sciaky Electric Welding Machines Ltd.

The fundamental difference between *fusion* welding—that is, gas and arc welding—on the one hand and resistance welding on the other, is that in the case of gas or arc welding the two parts to be joined are heated at their

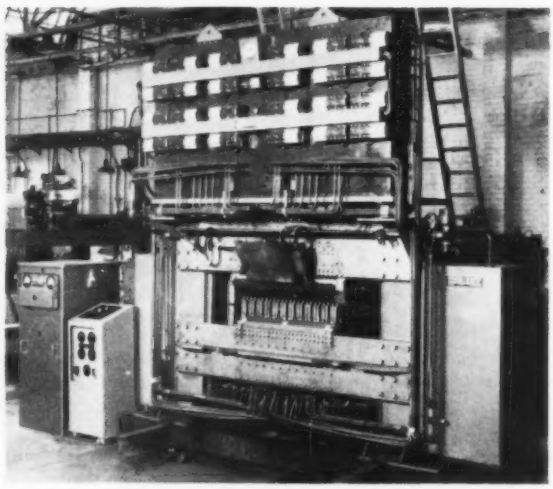


Typical 50 kVA power-operated spot welder fitted with electronic controls and used for general sheet metal work

junction faces to the molten state, then with the addition of further metal in the form of a feeder wire or electrode rod, a miniature puddling operation brings about the amalgamation of the two parts. As its name implies, the heat for the *resistance* weld is obtained by the passage of a low voltage high amperage current through the parts to be welded. It is not general for the parts to reach the molten state but they are heated until a plastic or forging temperature is reached and amalgamation takes place under heavy mechanical pressure. It follows that as no extraneous materials such as fluxes, filler rods, etc, are used, the metallurgy of the weld is not complicated by the addition of these materials.

Spot welding is undoubtedly the most popular form of resistance welding and machines are available varying from the manually operated type at round about £100 to the more complicated power-operated machine used for light alloys which can and does come into the region of £ thousands.

Speed of operation naturally varies with the type of machine used and the type of work for which it is used. The manually operated machine, working on the thinner gauges of mild steel, can produce welds in the order of practically 100 a minute, whereas the power-operated spot welder working under similar conditions is capable of anything up to six or seven hundred welds a minute.



A multiple electrode machine as used in the automobile industry

Portable spot welders in use in an automobile factory in India

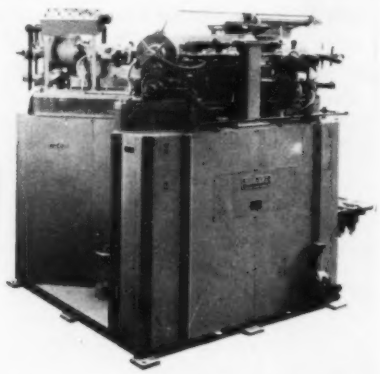
The increase in production speeds, and in fact the all-round improvement in the quality of weld obtainable from the spot welding machine, have come about largely by the introduction of electronic controls and power operation. To give an instance of the necessity for precise control in the making of a spot weld, it is interesting to note that a weld in, say, two thicknesses of $\frac{1}{8}$ in (3·175 mm) plus $\frac{1}{8}$ in light alloy is made in approximately $\frac{1}{50}$ of a second or less, and considering that in this short period the magnitude of the current is in the order of 200,000 A, and the metal is melted and re-formed, the necessity for using electronic controls for the current characteristics and timing is obvious. Some of the more difficult materials to weld call for a pre-heating cycle, a progressively increasing welding cycle, and a post-heating cycle, and these functions can be incorporated in the electronic control and will be reproduced in the making of each individual weld without any influence from the operator.

General Sheet Metal Work

As the function of a spot weld is in general to replace a rivet, it will be obvious that its most popular application will be in the field of the lighter gauges of sheet metal, and in this field undoubtedly the most important application is in the automobile manufacturing industry. The most popular machine for use in the automobile field and also in comparable sheet metal work is the pedestal type of

spot welder, power operated, rated in the order of 50 kVA, and with arms approximately 24 in (61 cm) long. This is a high-speed machine and is used for the assembly of many components which can be manipulated within its physical size and which are not too bulky to be carried to the pedestal type of machine.

Perhaps the most important machine, however, for the assembly of motor-car bodies and the like is what is known as the portable spot welder. A great deal of development work has gone into this type of machine and in its most popular form it consists of three parts: the transformer, the control gear, and the welding head or gun which is suspended from the transformer by water-cooled conductors. With the use of this kind of equipment the different parts of the motor-car body can be assembled or mounted on a jig or fixture and the operators move



Spot welder for the assembly of automobile wheels. Speed of production up to 400 wheels an hour

round the stationary fixture and make all the necessary welds.

Although there has been a certain amount of standardization of welding heads or guns it is still true to say that there are many hundreds, if not thousands, of designs necessary to cope with the intricate welding positions found in the design of a modern motor-car body. The use of the portable spot welder applies of course to any fabrication where it is easier to take the machine to the job than it is to take the job to the machine, and particularly where accurate jigging is concerned. Portable spot welders can operate up to 350 spots a minute and more, while portable seam welders compare favourably with their counterpart, the pedestal type.

The demand for increasing speed and accuracy is resulting in the use of more and more multiple electrode machines, and installations are in existence comprising anything from a small number of welds up to a thousand spot welds made in the same instant. The economy of such a set-up will be obvious. The difficulty in the design of machines of this type is due to the close proximity of the welds and the varying angles at which the electrodes have to be set, and it is therefore not possible always to get the whole of the welds or electrodes into one single machine. Several machines are therefore employed. These usually take the form of a number of multiple electrode machines and the transfer jigs or fixtures are moved mechanically from one machine to another. After each machine has accomplished its given number of welds, the completed component is ejected, and usually the jig returns automatically to its loading position.

A good instance of this type of set-up is that of the welding of the complete floor of a motor-car. These floors are assembled at the rate of 250 an hour with only one or two operators. Machines of this type are sometimes called 'transfermatic' machines, and a number have been sold from this country to the well-known motor manufacturers in Europe and other parts of the world.

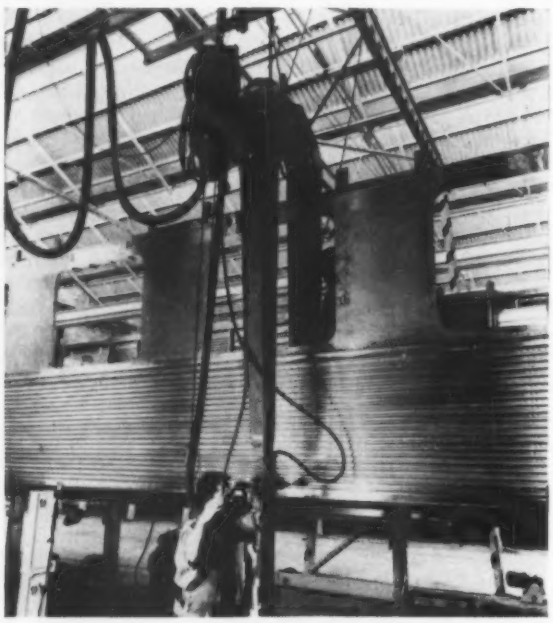
Another interesting example of this kind of application is in the assembly of automobile wheels. The conventional automobile wheel consists of two parts: the outer part or rim carrying the tyre, and the inner part or disc which is secured to the axle. The rim and disc have in the past always been joined together by riveting. With the advent of the tubeless tyre, the rim and wheel become part of the air chamber and must be airtight. Rivets are not always reliable in this respect and spot welding was introduced for this reason alone. It was not long, however, before it was found that spot welding using multiple machines was more economical in time and material, while from the point of view of the strength of the finished article it is interesting to note that instead of using twelve rivets, which was the conventional method, eight spot welds are now used, and the resultant wheel is considerably stronger than it was formerly. Not only has the time factor for assembling the rim and disc been shortened, but there has also been an economy in materials and manufacturing machinery.

Due again to the close proximity of the welds and the need for rigid electrodes and holders, it was not considered advisable to make the eight spot welds simultaneously, and the most popular machines work on the principle of making four spot welds automatically, indexing to the next position, and making a further four spot welds. This may sound a little cumbersome but in point of fact production from a machine of this type is in the order of 400 wheels an hour. Further development resulted in a

Universal seam welding machine used for gas- and pressure-tight joints

machine which did much more than the welding operation. This machine took individual rims and discs from the presses and carried out on a conveyor the operation of washing, assembly of the two parts by hydraulic pressure, welding, punching and coining the valve hole, chamfering the valve hole and painting. Production speeds of up to 1000 rims an hour are possible with this type of installation, again with the minimum of operators, and machines have been sent from this country to many Continental countries, and in fact behind the Iron Curtain.

Compared with the spot welding machine, the seam welding process does not find as great an application in the automobile industry. In appearance very much like the spot welding machine but fitted with wheels in place of the spot welding electrode, the seam welder produces a gas- or water-tight joint and therefore finds a very useful and economical application in the welding of petrol tanks, silencers, and things of that nature, while the portable type of seam welding machine is employed in attaching the drip mould to the car roof.

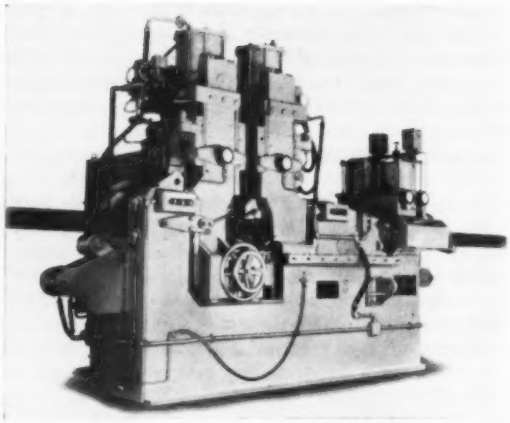


The assembly by portable spot welding of the side of a railway passenger coach

Railways

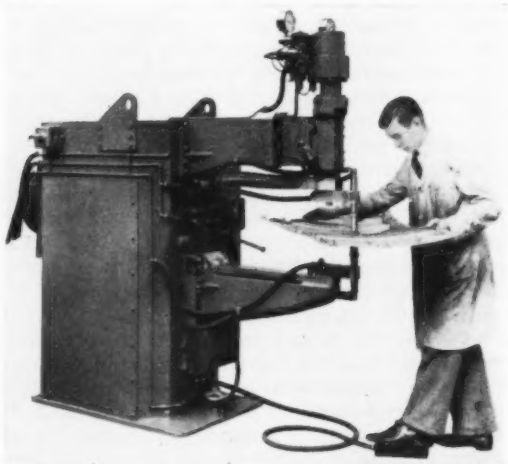
It is interesting to note that the French engineers have always been in the forefront in the development and use of resistance welding, and for some time before the second world war were using resistance welding in the manufacture of carriages, particularly for passenger trains. More recently this process has been adopted in Britain.

The principal application is to secure flat or slightly curved panels in light gauge steel to stiffeners to form the sides, roof, and ends of coaches. Appearance is naturally of great importance, particularly on the external surfaces of a railway coach, and from this point of view the appearance of rivet heads is not desirable. In general the fusion welding processes cause much distortion in the sheets and this becomes pronounced when the coaches are painted and varnished. Spot welding has therefore been given very serious consideration and production generally takes the form of assembling the sides, roofs, and ends as individual items. The units comprising these individual items are assembled on a jig and spot welded, and the assembled units are afterwards joined together to form the coach. The heat from the spot welds is so localized and takes place for only a portion of a second that distortion is prevented and great speed is obtained.



Automatic flash welder for joining railway lines into continuous lengths

The expectation of life of a passenger coach has of necessity to be many years, and it is important therefore that corrosion should be prevented or avoided, and with this object in view different kinds of corrosion-resisting steels are being utilized. These materials are alloy steels and often prove difficult in the welding process, and both pre-heating and post-annealing become necessary to avoid cracks in the welds. Another fertile ground for corrosion is at the inter-faces of the two parts which have to be welded, and to guard against this it is often necessary to paint the parts to be welded with a special paint and spot weld them while they are still wet. A good deal of research has gone into the composition of such paints and a variety of these is now available on the market for this purpose.

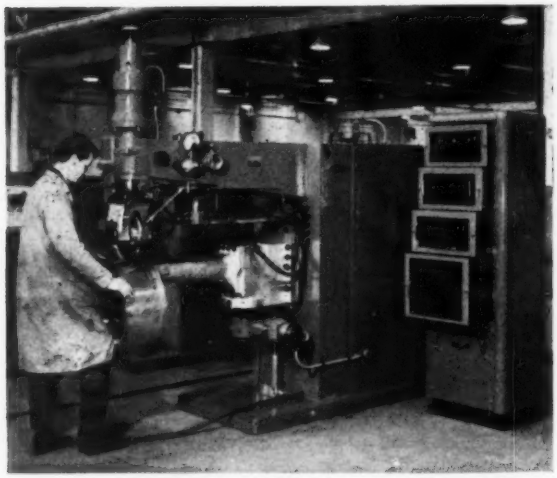


Stored energy spot welder used in the aircraft industry mainly for aluminium and its alloys

For many years it has been considered necessary for purposes of contraction and expansion to lay railway lines in relatively short lengths leaving a gap between each length. This has resulted in the familiar clickety-clack which we hear at all times on our railways. It has recently been found that there are other ways in which the problem of contraction and expansion can be overcome, and it is now becoming common in all countries for railway lines to be in one complete length. The flash-welding process is the one used for joining the short lengths of rails into one long length, and mobile machines have been developed so that this welding can be done on site.

Aircraft

The materials mainly used in the construction of airframes are usually aluminium alloys, duralumins, alclads, etc, and the spot welding of these materials, mainly of heat-treated character, calls for machines with very sensitive controls and high electrical capacity. Difficulties have, however, been gradually overcome, and during and since the war a great deal of production work has been carried



Seam welding a jet engine component

out on structures, generally of a secondary nature. Secondary nature usually means in the aircraft industry units which are not highly stressed or subjected to high fatigue, and have consisted in the main of engine cowlings, doors, instrument boxes, and internal fittings.

Further advances in the welding of these difficult alloys have, however, recently taken place, and both here and in America highly stressed parts such as wings, fuselages, tailplanes, etc, are now being assembled by spot welding. In fact, machines for this purpose have been sent all over the world. Light alloy material up to $\frac{3}{16}$ in (4·762 mm) plus $\frac{3}{16}$ in is being catered for, and the result is a streamlined surface free from indentation or protrusion consistent with an appreciable reduction in weight and economy of manufacture. Many of the more important aircraft flying in this country and the rest of the world at the present time are assembled by this method.

Jet Engines

It is often stressed by resistance welding engineers that an article should be designed specially for manufacture by the resistance welding process, and not adapted from some other means of manufacture. An important and typical example of pre-thinking in this direction is to be found in the modern jet engine. In fact it can be said that, had it not been for the resistance welding process, the jet engine would not have been with us in exactly its present form.

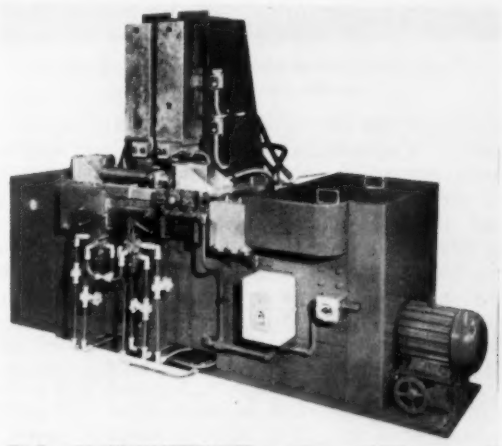
The materials used in jet engines are high tensile alloys designed to withstand high temperatures, and the stringent standards called for in the welded joints demand special features in the welding machine. Seam welding and spot welding are both used extensively in this type of engine, which is largely of sheet metal construction. Parts which are not made of sheet metal usually take the form of rings of various sections to which the sheet metal is secured. Originally these rings were made from forgings and the machining time was lengthy and costly. Such articles are now made from straight bar, circled, flash welded, and machined, and an enormous saving in time and money is made in the machining operation.

The welding of components of this type in conventional mild steel has been with us for many many years, but the materials we are dealing with now in the jet engine are in a different category altogether, and again call for an accurately controlled welding machine heavily built and employing pre-heat and an annealing cycle.

Constructional Engineering

Again the French have led us into what might ultimately become one of the most important applications for the spot welding industry. Until some years ago all constructional engineering was undoubtedly riveted. Later there followed the method of arc or fusion welding. The most recent development is, however, the assembly in the factory of trusses and other units by spot welding. These are then transported to site and eventually bolted together in position.

There were a number of difficulties to overcome in the welding of this type of work. Not only were the materials to be welded of heavy section generally, but there was the presence of rolling mill scale and a high degree of rust. By utilizing suitable current and pressure cycles in the machine, the necessity for cleaning off the rust and scale was eliminated. Machines which cater for this kind of work can handle a combination of plate thicknesses of 1 in (25·4 mm) plus $\frac{1}{2}$ in (12·7 mm) plus $\frac{1}{2}$ in, and comparable combinations.



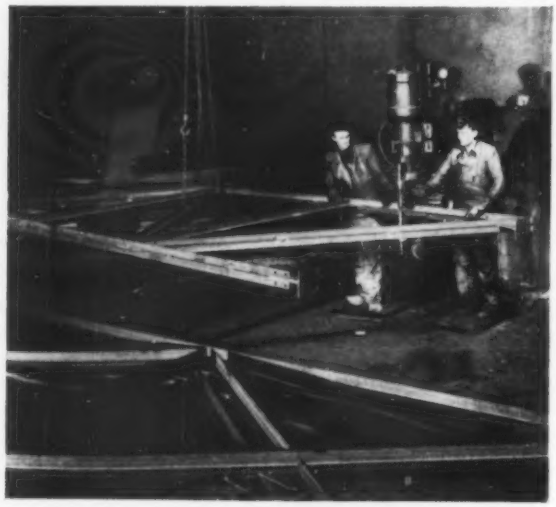
Flash welder for automobile rear axle assembly

This type of machine is relatively costly to manufacture as it embodies very high mechanical pressure and a range of welding currents, first to remove the scale and rust, and afterwards to make the weld and anneal. However, as it is confidently claimed that there is a saving of anything up to 30 per cent in labour by using this method of manufacture, the capital cost of the equipment is soon written off.

Three-Phase Welding

A question frequently asked is 'what is the most important recent development in resistance welding?', and there can be no doubt that the answer is three-phase welding. This answer may come as somewhat of a surprise, taking into consideration the progress that has been made in the application and use of resistance welding over the years, and some of the examples quoted in this article. However, the conventional machines have been practically identical right from the outset and it is only in the quality of controls, mechanical and electrical and electronic, that development has taken place, plus of course the application of resistance welding to unusual physical shapes.

Talking of three-phase, it is often said when referring to an invention or discovery that it was found by accident. That remark cannot be attributed to three-phase welding, although in the author's opinion the original intention

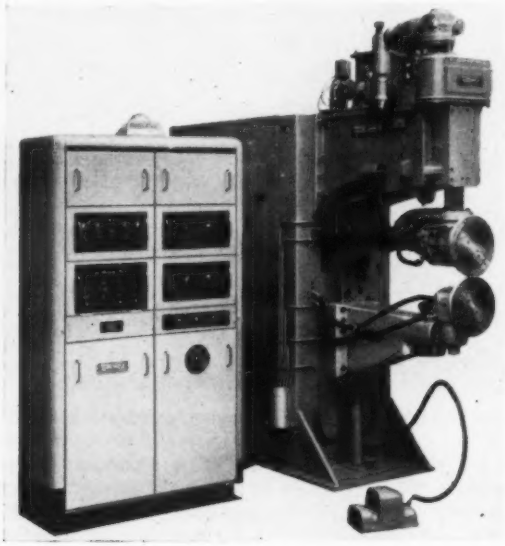


Three-phase spot welder used in the fabrication of trusses for steel building

was to meet the ever-present difficulty of electrical installation. Conventional resistance welding machines, with the possible exception of a few stored energy types, have always been made for connexion between two phases of a three-phase supply, or phase to neutral, and have reproduced a secondary current of sinusoidal waveform. This unbalanced load with its inherent low power factor has always presented difficulties and brought objections from the supply authorities.

Pursuing a solution to this supply and power factor difficulty has led to the creation of what is popularly known as 'three-phase welding', and the advantages which have perhaps fortuitously followed the process have, in the author's opinion, represented the biggest advances made in the industry. These include improved welding quality, a high degree of auto-compensation for such factors as change in inductance in the machine due to the amount of ferrous metal inserted between the arms of the machine, more tolerance in the growth of the diameter of the electrode, more control over the shunting of current through the previous spot weld due to its close proximity, and the ability to weld near to the edge of the workpieces. The life of the electrodes between trimming is also considerably increased. This is largely due to the absence of 'skin effect' found in the conventional 50 cycle supply.

Three-phase welding has in fact revolutionized many jobs that were previously considered borderline cases for spot welding. Notably among these are the heavier gauges of light alloys and also steel, constructional engineering, and the delicate heat resisting materials used in jet engine construction. The combined advantages to be gained by three-phase welding are, in the opinion of the author, outstanding, and it would not be surprising if in the very near future three-phase machines were the only ones to be considered for serious applications.



Three-phase seam and roll spot welder and associated control panel

The three-phase principle is equally successful in seam welding and projection welding, and more recently heavy flash welders have been produced in America embodying the system. The only slight drawback to the use of three-phase is that the system is a little more costly to manufacture, and therefore the initial capital cost is higher. This expenditure is, however, compensated by the reduced cost of installing this type of machine, less installed electrical supply, smaller cables and switchgear, etc, which, when added to the advantages quoted above, make the case for three-phase welding unquestionable.

Non-Destructive Testing in Welding

W. E. Schall, BSc, FInstP*

WELDING has probably been a more pressing reason than any other engineering activity for the rapid development in recent years of non-destructive testing.

The reason is that the welded specimen is a finished product of which the serviceability for a particular purpose has to be ascertained in such a way that no damage or strain is caused. The test cannot be 'destructive' nor indeed can it be one in which, say, 10 per cent of the work is examined under working conditions in the hope that if this fraction behaves well and is free from flaws, the same will be true of the rest.

It must not be assumed that from now onwards every welded seam should be non-destructively examined to find out whether or not there are flaws. Clearly there must be welds—and they possibly constitute the majority—which are not subjected to serious stresses and in which a void or inclusion here or there would not jeopardize the finished product. On the other hand there are seams—and the nuclear reactor pressure vessels are eloquent examples—in which every inch of weld must be examined to make sure that the unions are completely homogeneous and free from voids.

The decision as to whether or not an examination must be made, and, if so, whether it is to be 25, 50, or 100 per cent, must be made by those who design the work and superintend its progress.

By non-destructive testing is meant the application of a number of physical phenomena to detect, if possible, the presence of flaws which might impair efficiency but without in any way altering the physical or chemical characteristics of the specimen, and indeed in many cases without even touching it.

Types of Flaws and their Causes

As regards the flaws in welded seams which are to be revealed if present, they consist in broad outline of 'voids' or discontinuities which occur in the fused mass of parent body and welding metal. They are due to one or other of many different causes which can be identified by the names by which they are known, such as 'crack', 'lack of fusion', 'blowhole', 'incomplete root penetration', 'slag inclusions', 'gas pore', 'porosity', etc. The non-destructive method establishes the existence of the 'void' but except in radiography (to be mentioned later) it cannot do much more than that. The actual nature and cause of the discontinuity can only be assessed by the experience of the operator who makes the test or reviews the result.

Of the non-destructive methods which are employed, the oldest—apart from visual inspection—is probably the chalk and oil test. It served to detect cracks which are open to the surface and consisted of applying to that surface, after it had been cleaned, a layer of non-viscous oil. When the latter had been given time to seep into any crack, the surface was carefully cleaned and covered with a thin layer of chalk which then attracted the oil from the crack and thereby the latter was revealed. The trace of the crack on the chalk was clearly broader than the crack itself, and this was an advantage where hair line invisible cracks were concerned.

Use of Penetrant Liquids

The old chalk-and-oil method is still much in use but has been improved by the introduction of coloured penetrant liquids with lower viscosity and by using a 'developer' instead of plain chalk. The developer is a very volatile liquid and carries a chalk-like substance in suspension. When this is applied to the surface, evaporation leaves the white sediment behind and this then absorbs the coloured penetrant liquid from the crack as before.

A further development is to incorporate in the penetrant liquid a substance which fluoresces under ultraviolet light and then gives a brilliant indication when absorbed by the developer layer.

The next step was the use of iron or other magnetic particles to reveal cracks in the case of ferromagnetic materials. An object made of such material can be magnetized longitudinally by passing an electric current through a cable wound round it (Fig 1), or cylindrically (Fig 2) by passing a current through it. In both cases the magnetic field which is produced will stray into the air on encountering a crack which may be either on the surface or below it, but only if the plane of the crack is approximately normal to the magnetic field (Fig 3 a and b). When that plane coincides with the field (Fig 3c) no straying takes place. Magnetic particles in the form either of a

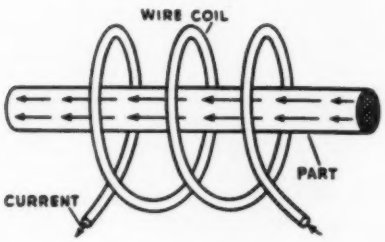
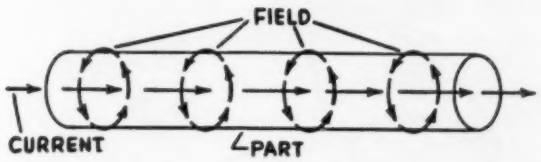


Fig 1 (left) *shows the principle of longitudinal magnetization and Fig 2* (below) *illustrates cylindrical magnetization*



* Director, Solus-Schall Ltd.

powder or in suspension in a highly volatile liquid will, when applied to such a surface, move towards the straying magnetic field and so reveal the crack. Magnetization of the object may be by means of permanent magnets or, more generally, by one of the several designs of magnetizing equipment which are made for the purpose (Fig 4).

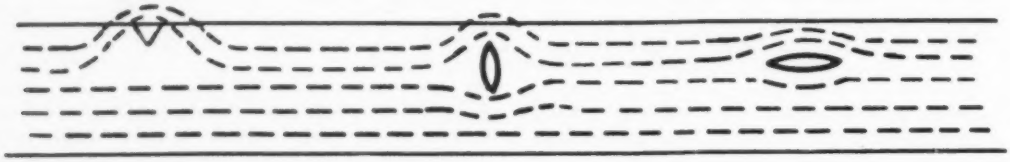


Fig 3. This diagram illustrates the effect of (left) *lines of magnetic force round a surface crack;* (centre) *lines of magnetic force round a sub-surface crack at right angles to the magnetic field, and* (right) *lines of magnetic force round a sub-surface crack which is parallel to the magnetic field*

So far we have dealt with the non-destructive methods which were in use before the 1914–18 war and their development since then.

The discovery of X-rays by Röntgen took place in 1895, but in spite of the fact that he had then already made some radiographs of metallic objects, twenty years went by before radiography was used for any purpose other than medical diagnosis of the human body. The reason was that with the apparatus which was available in those early years, any thickness of steel greater than about ¾ in (19 mm) would cast a total shadow on a photographic film without any indication of detail, because the rays were not sufficiently penetrating.

In 1913 the Coolidge tube—the first example of an X-ray tube with a hot cathode—became available and this, together with the closed core high-voltage generator which took the place of the spark coil and interrupter, made rapid progress possible.

The depth of penetration of X-rays depends on two factors: (1) the voltage which is applied to the ends of the X-ray tube, and (2) the density of the material through which the rays have to pass. Steel, being much denser than human flesh and bone, requires higher voltages for radiography. Medical work calls for 50-100 kV, while industrial radiography—notably for steel—begins at 150 kV and goes up to 400 kV or even more.

In the examination of welds the X-rays pass through the object to the film, where they affect the sensitive emulsion as does visible light. In passing through the object the rays are differentially absorbed. Thicker sections of steel absorb more than thinner ones and the latter again absorb more than cavities filled with slag or air. The radiograph on the film therefore is a shadow of the object in which cavities which have absorbed the least amount of rays appear blackest, followed by the thin sections and then the thick sections of the object. Of all the methods mentioned in this article, radiography is the only one which does more than merely indicate the existence of a 'void' or crack in a weld. It can give an accurate representation of the size and shape of the flaw and, in addition, it can give some details of the contents and structure of the flaw from which its cause and possible danger can be assessed.

Weld radiographs generally require to be made 'on site'—that is, on the pipe-line, on the nuclear reactor shell, or on the welded steel structure. The X-ray unit must therefore be transportable. Up to voltages not exceeding 300 kV it is possible to assemble the high-voltage generator and the X-ray tube together in one single oil-filled tank (Fig 5). Above 300 kV it is necessary to separate the X-ray tube from the generator and to connect the former to the latter by means of shockproof cables as in Fig 6. In both cases the X-ray tube can be accurately positioned in relation to the welded seam by means of suitable supporting gear.

The production and interpretation of weld radiographs are subjects which are far beyond the scope of this article. With the exception of some very brief notes, it must suffice

Fig 4. A typical mobile magnetizing unit

Fig 5. A portable X-ray unit for 260 kV operation

to say that both activities call for considerable specialist skill and knowledge. Often the making and the reading of the film are entrusted to independent individuals.

The quality of the radiograph is governed by correct attention to such factors as voltage, positioning of X-ray tube and film, size of focal spot, distance of focus to object and film, etc, apart from the details of purely photographic procedure. Mention has already been made of the relation of penetrating power of X-rays to the applied voltage. For steel the values are as follows:

kV	Steel thickness	
	ins	mm
100	$\frac{3}{4}$	15·875
150	$1\frac{1}{4}$	31·75
200	$2\frac{1}{4}$	57·15
250	$2\frac{1}{2}$	63·5
300	3	76·2
400	4	101·6

If the voltage is too low or too high there will be absence of detail on the radiograph.

Importance of Tube Positioniong

Positioning of tube and film is of particular importance and can, if there is some prior knowledge of the location of the flaw derived perhaps from ultrasonic examination (to be mentioned later), exert a very great influence indeed on the value of the radiograph. To take but one example: if the direction of the rays is in the plane of a crack, a clear shadow of the latter will result, but if the rays and the crack are at right angles to each other there will be practically no indication at all. The reason for this can be seen in Fig 7, where on the left the rays, in the plane of a crack, pass through a layer of air or gas as thick as the object on their way to the film, and therefore there is a strip of considerable blackening on the radiograph. On the right, the plane of the crack and the direction of the rays are normal to each other and the slight thickness of air or gas makes practically no difference to the intensity of rays reaching the film.

This is an extreme example of the effect of positioning but, in general, matters must if possible be so arranged that a flaw is not covered by a thick part of the object and so rendered less visible than it could be.

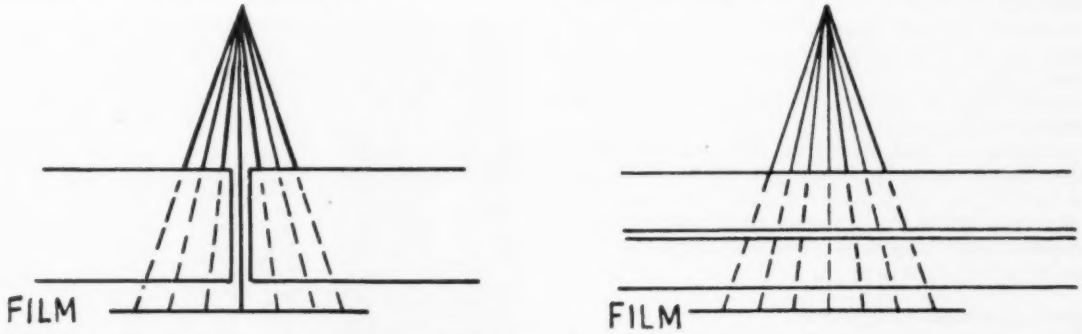


Fig 7. This diagram illustrates the importance of correct positioning of the X-ray tube and film in crack detection. The left-hand diagram shows the effect when the crack is parallel to the direction of the rays, while the diagram on the right shows the effect when the crack (lamination) is at right angles to the direction of the rays

The size of focal spot and the distance from it to the flaw and film greatly influence the sharpness of the image on the radiograph. In Fig 8 a focal spot of some size is seen to produce a 'penumbra' around the shadow on the film, while Fig 9a shows how this half-shadow is reduced when the object is moved near the film, or further away from it (Fig 9b). The penumbra causes what is known as geometrical unsharpness and impairs the quality of the film. While the size of the focal spot cannot be altered when once the X-ray tube has been made, the production of penumbra can be reduced by bringing the object (in this case the flaw) as near the film as possible or by increasing the focus film distance.

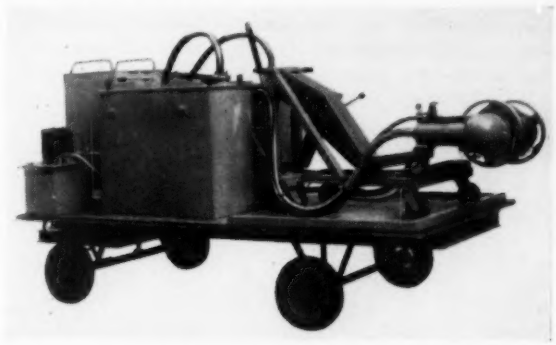


Fig 6. A 300 kV X-ray unit assembled on a low trolley

It is always difficult to give a 'negative' diagnosis—that is to say, to state definitely that there is no flaw in a weld when there is no indication on a radiograph. The radiographer who makes the picture goes some way towards overcoming this by determining the 'sensitivity' of the conditions under which the radiograph was produced. To do this he uses a 'penetrameter' which consists of a collection of wires of ascending thickness or a step ladder also of ascending thickness, both of which are made of the same material—in this case steel—as the object. The penetrameter is placed on the side of the object towards the X-ray tube and, when the radiograph is finished, note is taken of the smallest diameter of wire or the smallest thickness of step which is still visible. This dimension is then the minimum thickness of flaw in the direction of the rays which can still be expected to show up. The report can then state that any flaws of size greater than this minimum which do not appear on the radiograph do not exist. There may be others which are smaller and their detection cannot be guaranteed. The dimension is expressed in terms of the total thickness of the object and as a percentage. It is called the sensitivity. Thus if an

object is 4 in (102 mm) thick and a $\frac{5}{64}$ in (2 mm) wire or strip is still visible, the sensitivity is said to be 2 per cent.

The interpretation of the radiograph is largely a question of experience coupled with knowledge of welding practice. A British Standard, No 499 Part 2: 1958, contains a glossary of terms relating to weld flaws as seen in radiographs and in Fig 10 is a group of four radiographic images of welds in each of which some particular kind of imperfection is apparent. The literature which is devoted to this subject has now assumed considerable dimensions

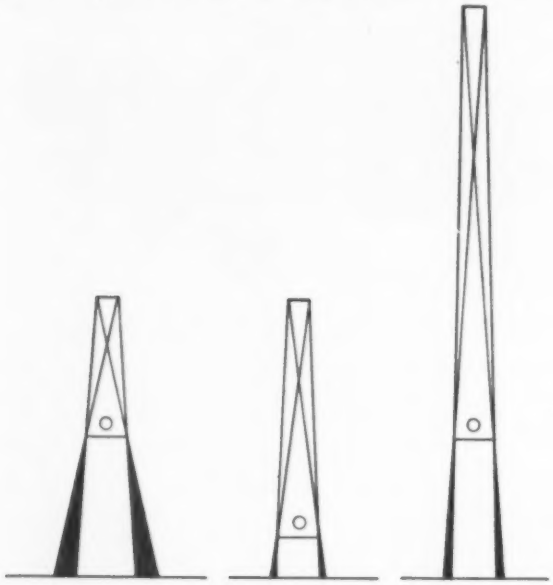


Fig 8 *Fig 9a* *Fig 9b*

Diagrammatic representation showing how the 'penumbra' effect produced by a focal spot of some size (Fig 8) can be reduced by moving the object nearer the film (Fig 9a). The same result can also be achieved by moving the focal spot away from the film (Fig 9b)

and the reader is advised to consult it for further information.

Reference has already been made to the lack of penetrating power of X-rays when they were used for industrial purposes in the first world war. At that time the difficulty was overcome by the use of radium. This element spontaneously produces gamma rays which differ from X-rays only in wavelength, but are similar to them in all other respects. They have the penetrating power which X-rays would have if generated by two million volts, and they can pass through some 9 inches (229 mm) of steel. The trouble about using radium was its scarcity and consequently its very high price.

Isotopes in Industrial Radiography

The discovery that uranium fission can give rise to radioactive isotopes of other elements like cobalt, iridium, tantalum, and thulium made possible the general use of gamma rays for industrial radiography. The isotopes are produced at the UKAEA Establishment at Harwell and are supplied in cylindrical capsules 2 by 2, 4 by 4, or 6 by 6 mm. They are housed in bronze containers lined with tungsten alloy which heavily absorbs the rays and therefore protects the operators. Compared with an X-ray unit, the gamma ray source container is light and easy to handle. Moreover, it costs much less. Its mode of application where it takes the place of the X-ray tube is very similar to that of the X-ray unit.

In spite of these advantages, however, gamma rays are not universally applicable for a number of reasons. First, the sources, even in the largest 6 by 6 mm size, have an output of radiation which is a small fraction of what an X-ray tube running at quite a moderate current can produce. Consequently the exposures tend to be very prolonged. Where the X-ray unit will work in minutes, the gamma ray sources need hours.

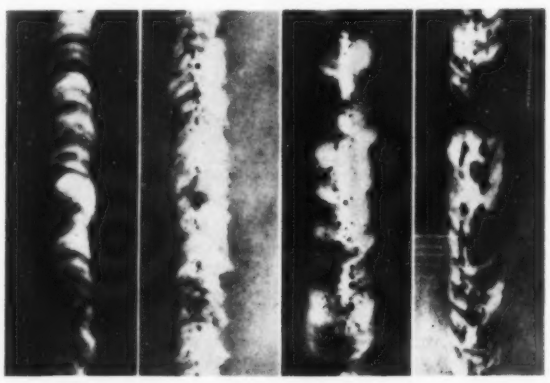
Second, the dimensions of the sources—even the smallest—are equal to, or larger than, the largest X-ray focal spot and therefore give rise to much geometrical unsharpness.

Third, the rays from a gamma source are monochromatic. That is to say, they have a line spectrum with generally one characteristic wavelength, while the X-ray tube produces a beam with a continuous spectrum. The latter provides more contrast and therefore more identifiable detail in a radiograph than does the former.

The result of these features is that X-rays are used wherever possible, and especially where accurate detail work up to 400 kV is required. Gamma rays are used when the object is so shaped or placed that access with X-rays is impossible and where the density or thickness of the object makes it imperative to use rays at more than 400 kV. X-rays and gamma rays are complementary and not supplementary in industrial radiography.

Controlling Radiation Hazards

A brief reference might here be made to radiation hazards. The dangers which attend the indiscriminate exposure of the human body to X- and gamma-rays have been known or suspected since shortly after their discovery. The knowledge has become public property since the coming of the atom bomb and the use of nuclear energy. Fortunately the whole subject is receiving careful study by a number of committees whose findings are or will be incorporated into the Factory Act and similar legislation. Thereby both the general public and the users of penetrating rays will learn what are the dangers and



a b c d

Fig 10. Some typical X-ray photographs of weld seams: (a) *shows a faultless weld:* (b) *reveals the existence of small pores;* (c) *shows large pores; and* (d) *reveals slag lines at both flanges. (Courtesy R. Berthold, Atlas 1938/44)*

will receive such protection from wanton or careless misuse as the law of the land can give.

The engineering industry to whom this article is addressed is already subject to protective legislation covering the hazards inseparable from its work, such as electric currents, high voltage, poisons (lead, cyanide, acids), rotating machinery, and so on, and to which are now being added the hazards of radiation.

The search for cracks in the whole of a welded seam by means of X-rays can be very costly both in time and money. There are cases where this is necessary, but in many others it would suffice to radiograph parts which are suspect as a result of other tests. Here the ultrasonic method which came into action after the second world war is yielding valuable results.

Ultrasonic Testing Techniques

Ultrasonic flaw detection is a form of radar in which a mechanical pulse, piezo-electrically produced in a quartz crystal, is transmitted from the latter into the object. There it travels till it reaches a boundary, which may be a crack or the back wall of the object. In either case it is thrown back and when it again reaches the crystal it is once more converted into an electric pulse which can be recorded on a cathode-ray tube. The trace on the fluorescent screen indicates not only the presence of a crack or 'void', but gives the distance of the latter from the crystal.

Fig 11 shows the apparatus and a diagrammatic representation of the method of flaw detection.

The apparatus on the left provides the high-frequency voltage which causes the crystal probe at the left-hand end of the diagrammatic steel bar to oscillate. The mechanical vibrations are transmitted into the object (steel bar) by contact and travel to the far end or to a discontinuity in between. In either place they are reflected and return to the crystal to be reconverted into an electric voltage.

The transmission and echo pulses are made visible on the fluorescent screen of a cathode-ray tube which can be seen in the top left-hand corner of the apparatus. The screen with its scale is reproduced in diagram above the object (steel bar). The pulses are recorded vertically while a linear time base moves them horizontally to the right. We therefore get a transmission pulse close to the zero line on the left. The echo pulse from the end of the bar can be seen to the left of the scale division 5, while the echo from an intermediate discontinuity appears to the left of scale division 3.

When the velocity of the ultrasonic wave in the object is known, the distance of the back wall or any intermediate discontinuity can be read directly from the cathode-ray scale.

As in the case of radiography, the ultrasonic detection of flaws has developed into a large subject and speciality, and the reader is referred to the literature for details. The method cannot give the information about a crack or void in a weld which can be obtained from a good radiograph; it can, however, detect and very rapidly locate such flaws. Moreover, it can indicate the direction of the flaw and so assist not only towards a decision to radiograph but also towards the problem of positioning.

Radiography and ultrasonic flaw detection are in many ways complementary. Thus X-rays are completely absorbed by a few inches of steel, the actual thickness depending on the wavelength of the rays. The ultrasonic beam, on the other hand, can travel undiminished for

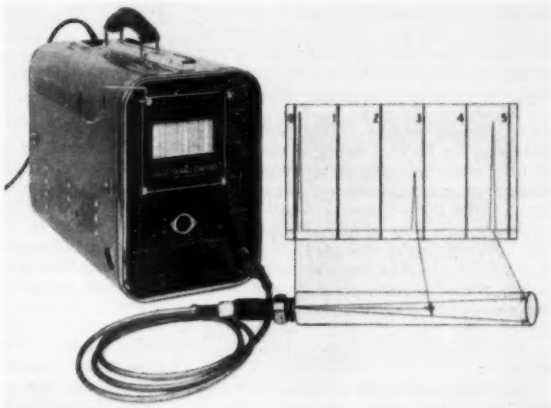


Fig. 11. Ultrasonic flaw detector equipment with a reproduction of a typical trace on the cathode-ray screen revealing the existence and position of a flaw

many yards in a homogeneous steel bar. X-rays, when they encounter an air-filled discontinuity in their path, go right through it with virtually no change in intensity. The ultrasonic beam, however, is completely stopped and reflected at such a boundary.

In conclusion one can say that of the modes of non-destructive testing—penetrants, magnetic particles, X-rays, gamma rays, and ultrasonics—the method of choice for accurate work is unquestionably X-rays, with gamma rays as a second string where for any reason X-rays cannot be applied. Ultrasonic flaw detection is a most useful accessory to X-rays, to act more or less as a path finder. Penetrants and the magnetic particle method can be used for cracks and flaws which are open to the surface and occasionally also for sub-surface cavities.

Notes

Gold Medal for BEAMA Exhibit

The premier Gold Medal of the 1959 Rand Easter Show was won by the collective exhibit in the new UK Pavilion.

This was the first time that the UK had provided a pavilion in the international section of the Show, and the theme chosen for this inaugural exhibit was 'This Atomic Age'—one of the fields in which Britain leads the world. The display, organized by the Southern African Overseas Committee of BEAMA, featured the achievements of the British Electrical and Allied Industry in developing power for the service of mankind from three main sources: coal and oil, water, and the atom.

The opening section of the exhibit was dominated by portrait busts of three great British pioneers: Faraday, Watt, and Rutherford, specially commissioned from Rhona Stern, the well-known South African sculptress. The bust of Faraday forms the front cover picture of this issue. At the close of the Show these busts, with their related models of equipment, were presented to the University of Witwatersrand for permanent display in the electrical engineering, mechanical engineering, and physics departments.

The Rand Easter Show, now in its 48th year, is the most important exhibition in Africa. Originally concentrating on agriculture and livestock, it has now developed into an international industrial exhibition, and during its two weeks' run this year it was visited by 629,000 people.

New BEAMA Domestic Appliances Division

In recognition of the importance and size of the domestic electrical appliances industry in Great Britain, the BEAMA Council has set up a separate Division to cater for the needs of member-firms in this field. This development was mentioned by Mr S. F. Steward, Director of BEAMA, in his speech at the British Electrical Power Convention when he opened the discussion on Mr Irens' paper (see p. 115 of this issue).

The new Division works under a Domestic Appliance Divisional Board composed of managing directors and directors of ten of the leading manufacturers in this field and provides an influential and authoritative body to speak for the domestic appliance industry. Its terms of reference are: 'To promote the interests and progress of the British Domestic Electrical Appliances manufacturing industry and to provide a forum for the discussion of all matters affecting the industry both at home and overseas'.

One of the first duties of the new Division is to collect and disseminate statistics of electrical appliances in place of those previously dealt with through the Board of Trade, and the BEAMA has undertaken to provide this service on behalf of the whole industry.

The Domestic Division is represented on the Conseil Européen de la Construction Electro-Domestique.

Duke of Edinburgh to be Patron of IEA Exhibition

His Royal Highness the Duke of Edinburgh has consented to become Patron of the Instruments, Electronics, and Automation Exhibition which will be held at Olympia, London, next year. His Royal Highness has always taken a great interest in scientific and industrial matters, and this honour is a further instance of his appreciation of the importance of the application of science to industrial development.

The IEA Exhibition is being promoted by BEAMA and five other leading trade associations: the British Industrial Measuring and Control Apparatus Manufacturers Association, the British Lampblown Scientific Glassware Manufacturers Association, the Drawing Office Material Manufacturers and Dealers Association, the Electronic Engineering Association, and the Scientific Instrument Manufacturers Association of Great Britain.

GEC Arabic Catalogue

The General Electric Co Ltd has recently issued a catalogue in Arabic. It is being sent initially to heads of governments and educational bodies in the Arabic-speaking world and to GEC agents who will distribute it to contractors and dealers in the Eastern countries, including Bahrein, Iraq, Jordan, Kuwait, Lebanon, Syria, Qatar, Trucial Coast, Muscat and Oman, Saudi Arabia, Aden, Egypt, Libya, Tunisia, and the Sudan.

Although described for convenience as 'catalogue', this new publication is something of a handbook as well, designed to tell a man with little training such things as the meaning of earthing a circuit, or to explain to an inexperienced contractor how to wire a house. The contents were carefully translated so that all the technical terms were turned into understandable Arabic and line drawings were added where necessary to make the descriptions absolutely clear. The book was printed on a paper specially produced to be tough and long-lasting in all the different climatic conditions in the various countries where the book will be used.

The basic purpose of the catalogue is to provide information and help for the growing number of small electrical contractors in the Arabic-speaking countries who are not highly trained men. It therefore starts with the basic principles of electricity and explains terminology and practical aspects. It goes on to its main concern—installation materials—in a logical order through the sequence of a wiring installation, so building up a picture of a complete job. Each chapter has a section giving additional helpful information, such as measuring instruments and installation tests, descriptions of different types of motor and reasons for the choice of type according to circumstances, and so on.

Also included are details of some products for which there is a ready market in the countries concerned, such as street lighting, radio, domestic electrical appliances, and electro-medical equipment.

'The Technology of the Gas-cooled Power Reactor'

The United Kingdom Atomic Energy Authority produced under the above title a collected volume of 17 papers presented by members of its staff at the Second International Conference on the Peaceful Uses of Atomic Energy held in Geneva in September last. The papers describe the work carried out by the Authority in collaboration with the British nuclear industry from Calder Hall onwards and provide the background to the nuclear power stations now being installed in Great Britain and offered for export to countries overseas.

The Authority has now made it known that although the book was produced primarily for distribution to overseas organizations likely to be concerned with the development of nuclear power, a limited stock is still held by the Authority, and requests for copies will be considered from organizations with a genuine interest. Such requests should be sent to the UK Atomic Energy Authority Public Relations Branch, 11 Charles II Street, London, SW1.

Electricity in Horticulture

At this year's Chelsea Flower Show the exhibit of the Electrical Development Association was larger than in recent years. Electrical horticultural equipment for every type of grower was on view, showing how electrical methods and techniques save labour, improve efficiency, increase productivity, and bring early cropping.

The main feature of the exhibit was a completely automatic greenhouse where soil warming and heating were thermostatically controlled and all ventilating and watering were done automatically.

'Midsummer Day Fare'

A novel 'Midsummer Day Fare', held on midsummer day—June 24th—was the first major exercise in electric cooking arranged by the Modern Cooking Promotional Committee—a body formed early this year by nine of the leading British manufacturers of domestic electric cookers.

At the demonstration, emphasis was placed on the grill of the modern electric cooker and nine new original grills catering for all tastes and all pockets were cooked in front of the audience.

The demonstration was preceded by a short address by Professor John Yudkin, a well-known nutrition expert, and some introductory remarks by Mr A. S. Oldhams, Deputy Chairman of the Modern Cooking Promotional Committee and Sales Director of the Electrical Division of Radiation Ltd.

Mr Oldhams stressed the many advantages of electric cookers, notably their economy, speed, flexibility, freedom from fumes, and automatic 'timed' cookery. At the end of the demonstration, he revealed that the total energy consumption of the nine cookers used for preparing the nine different grills displayed amounted to only 7 units of electricity.

The member-companies of the Modern Cooker Promotional Committee, who each provided a cooker and a demonstrator for the exercise, are:

Allied Ironfounders Ltd
Belling and Co Ltd
Carron Company
English Electric Co Ltd
General Electric Co Ltd
Electrical Division of Radiation Ltd
Revo Electric Co Ltd
Simplex Electric Co Ltd
Tricity Cookers Ltd

The Engineering, Marine, Welding and Nuclear Energy Exhibition

HELD this year for the twenty-second time since 1906, this comprehensive and extremely interesting exhibition occupied all the three halls at London's Olympia, comprising more than 250,000 square feet (23,000 m²) of stand space.

The principal sponsoring organization is the British Engineers' Association, supported by the BEAMA and the following organizations: the British Acetylene Association, the Institute of Welding, the Nuclear Energy Trade Associations' Conference (NETAC), the Society of Motor Manufacturers and Traders (Marine Section), and the Electric Welding Industry Committee of the BEAMA.

'Nuclear Energy' was first included in the title of the Exhibition in 1957—a recognition of the fact that a large number of British engineering firms are now involved in one way or another in the many aspects of nuclear engineering. Consequently, a large proportion of the exhibitors were displaying examples of nuclear equipment or research work on their stands and were not therefore geographically separated in a 'Nuclear Section'.

The Welding Section, however, formed a separate entity occupying the whole of the ground floor of the Empire Hall and was in effect an 'exhibition within the Exhibition'. Here BEAMA member-firms comprised almost one-third of the total exhibitors and nearly half the stand space.

The Exhibition was formally opened by Sir Edward Thompson, JP, the Honorary President of the Exhibition, President of the British Engineers' Association and Chairman of John Thompson Ltd. Here are some of the points he made in his opening speech.

'The British engineering industry has more than kept pace with the rapid expansion of industry throughout the world. To-day in Britain, one out of every seven employed persons is engaged in engineering, while the gross output of the industry has reached an annual value of £6000 million.

'One section of the Exhibition is devoted to welding, a branch of engineering technology in which some spectacular advances have been made during the past two years. There are two main reasons for this. The first is the rapid growth of automation throughout industry, which has resulted, as you will see, in a great many new types of multi-head automatic welding machines designed for special purposes. The second is the achievement of extremely high quality in the welding of both new and conventional material for atomic reactors.

'Among the problems presented by this branch of engineering is the need to discover ways of fabricating—for example, reactor fuel cans—out of new and highly recalcitrant metals, which must then withstand exceptional conditions of temperature, pressure and radioactivity in a reactor core. British designers of welding equipment have met this challenge; out of six thousand magnesium fuel cans searchingly tested after fabrication, only seven were rejected. In the construction of the reactor pressure vessels also, unusually high standards are demanded of the welding industry, and new techniques to meet these are continually being developed.'

Stand-by-Stand Review of BEAMA Member-Firms' Exhibits

Aiton & Co Ltd. As specialists in pipework, this company showed a comprehensive range of high and low pressure pipework in carbon and alloy steels, expansion fittings and steam traps. Examples of welded pipe joints and Corwel joints were exhibited; also constant load pipe supports and fluid mixers. Another of the firms' products—evaporator-distillers for land and marine use—were also prominent on the stand.

W. H. Allen Sons & Co Ltd. Many of the exhibits on this stand were new or improved designs shown for the first time.

The largest equipment was a 330 kW marine auxiliary diesel dc generator comprising a pressure-charged 6-cylinder 750 rpm 480 bhp V-form diesel engine directly coupled to an Allen dc generator. This type of set is also constructed in normally aspirated form and is representative of a wide range of sets for power outputs of 180 to 636 kW. The range of vertical in-line units covers 3 to 8 cylinder sizes with power outputs from 75 to 424 kW.

Two alternators were shown. One was a 400 kW, 500 kVA, 0·8 pf, 750 rpm open drip-proof alternator for diesel drive, with a flexibly-coupled shunt exciter and voltage control by a carbon pile automatic voltage regulator. The second was rated at 500 kW, 625 kVA, 0·8 pf, 1800 rpm, with the Allen self-regulating and static excitation equipment which was fully described in our last issue.*

A recent development was featured in another interesting exhibit—a model of a 110 kW, 110 V shaft-driven dc generator which was a replica of the equipment recently built for two new motor tankers. Since the generator is driven by the ship's main engine, this arrangement dispenses with an auxiliary engine and thus saves cost, space, maintenance, and spares.

Finally, another major item was a steam turbine rotor for a 1750 kW marine auxiliary pass-out pass-in turbogenerator for one of four sets to be installed in the 27,500-ton Orient liner *Oriana* now under construction. The rotor is manufactured from a solid forging of 3 per cent chromium-molybdenum steel, the wheels being integral with the shaft.

An arresting feature on the stand of the **BTH and AEI Heavy Plant Division** was a large pictorial display of the turbo-electric propulsion equipment for the 85,000 shp twin-screw liner SS *Canberra* now being built at the Belfast Yard of Harland & Wolff Ltd. A big point of this equipment is that when the ship is cruising, the electric drive will allow 40,000 shp to be delivered with one turbine powering both screws, the other turbine and its associated auxiliaries being shut down.

Another interesting exhibit was a 450 kW, 440 V, 3-phase, 60 c/s auxiliary geared turboalternator set—one of four on order for two new P & O 18,000-ton tankers.

Next were two pieces of equipment specially designed for British Admiralty requirements. One was a permanent magnet high-frequency single-phase generator developed by BTH; a machine of a very compact design with a fabricated steel frame to withstand shock. Its electrical output is 1·5 kVA at 110 V when running at 2400 rpm. The other was the result of a request by the Admiralty for a number of electrical manufacturers to collaborate in the design of a single magnetic amplifier type of voltage regulator, and a prototype model built under an Admiralty development contract was shown. This regulator is suitable for the control of a wide range of 60 c/s generators.

* THE BEAMA JOURNAL, **66**, No 2, pp 51-3.

Demonstrations were given of a propeller tachometer equipment developed by BTH in conjunction with Hardings (Leeds) Ltd which indicates direction and speed of a ship's propeller, and counts the revolutions. A selsyn transmitter is coupled to the ship's propeller shaft and drives two selsyn receivers, one in the engine room and one on the ship's bridge.

Industrial equipment shown on the stand including a vertical high-frequency motor alternator supplying power to a Birlec packaged induction heater. This equipment was reviewed on page 120 of THE BEAMA JOURNAL of August 1958.

The large stand of **Babcock & Wilcox Ltd** was devoted to a series of excellent pictorial displays and models showing the company's wide interests in the fields of nuclear energy, supercritical-pressure steam generation, marine and general engineering.

A prominent feature was the painting by Claude Buckle showing the nuclear power station at Hinkley Point in an advanced stage of construction. This painting was specially executed for the British Electrical and Allied Industry's Exhibit at Brussels last year* and had not been shown in this country until this exhibition.

Accompanying this painting were sectioned models of one of the Hinkley Point reactor groups and a steam-raising unit, both these models having been first exhibited at the Second United Nations 'Atoms for Peace' Exhibition† in Geneva last autumn and now shown here for the first time in Great Britain.

Supporting displays in the nuclear engineering section dealt with the company's facilities for the production of a range of components such as pressure vessels and containment buildings, steam-raising units, reactor components, research equipment; for services to industry for machining, welding, heat treatment, and so on, and with the manufacture of plant for the Hinkley Point station, including the 400-ton Goliath crane.

Another display dealt with the basic principle of 'once-through' steam generation, with particular reference to generation at supercritical pressures. An animated colour diagram and other illustrations compared the principles of natural circulation and 'once-through' types of boilers and showed the improvement in thermal efficiency with supercritical-pressure generation.

Cyclone firing was described and illustrated by animated diagrams on a continuous-loop film and by photographs of Cyclone-fired boilers under construction and in service, including one of a Radiant-type boiler with three Cyclone furnaces at the Barking station of the CEGB.

On the stand of **Birlec Ltd** an up-to-the-minute news service was in operation by teleprinter, the significance being that component parts for the Creed teleprinter are heat treated in Birlec furnaces.

Demonstrations of the process in a newly developed 20 kW 'hump-back' mesh belt conveyor furnace were the principal feature of the exhibit. The name is derived from the appearance of the furnace: the centre section is raised to ensure that the heating chamber is positively filled with protective atmosphere gas maintained at a small pressure and burnt at the ends of the downward-sloping outlet and inlet tunnels. The atmosphere gas, which is lighter than air, is retained in the elevated muffle fitted in the heating chamber with minimum loss at the ends, and it is claimed that the flow of protective atmosphere is much less than that required for the conventional 'straight through' furnace.

Among the many varieties of metals and tubes shown by the **Birmingham Battery and Metal Co Ltd** was one of the heaviest condenser plates in yellow metal produced in this country. It weighed 2½ tons, was 10 ft 6 in (3·2 m) in diameter and 1¼ in (32 mm) thick. Condenser plates in other metals, including naval brass and aluminium bronze, were also shown. Condenser tubes in various copper base alloys, and copper tubes up to 24 in (61 cm) diameter and brass tubes up to 18 in (45·7 cm) diameter; hot rolled sheets in aluminium brass, copper nickel, and deoxidized copper; solid and tubular HC copper busbars, and corrosion-resisting bimetal tubes were also among the wide range of the company's products.

The Industrial Gear Division of **David Brown Industries Ltd** was showing a wide range of gears, gear boxes, gear type flexible couplings and gear cutting tools as part of a combined exhibit of the David Brown Companies. Technical data on the leading types of these gear units appeared in an article in the May 1959 issue of THE BEAMA JOURNAL.

Campbell & Isherwood Ltd designed their stand to draw attention to their standard range of electrical products for marine and industrial applications, and to the branch facilities available for electrical work and repairs in the leading ports of Great Britain and in Antwerp.

The products shown included a selection of standard marine pattern ac motors for engine-room auxiliaries, a marine pattern alternator, a number of standard floodlights and lighting fittings, and working models of gravity davits.

The main feature on the stand of **Drysdale & Co Ltd** was a 32 in (81 cm) horizontally inclined axial flow main circulating pump for the new P & O liner *Canberra*. This was accompanied by several other types of pumps, including a rotary self-priming marine pump, and gear type and centrifugal tank type pumps for forced oil lubrication. Other marine and industrial pumps were shown in the form of models.

George Ellison Ltd devoted most of their stand to their well-known switchgear. The principal item was an 11 kV 250 MVA circuit-breaker unit, ASTA tested to BS 116: 1952 and complying with BEBS–S2, complete with an 11 kV 250 MVA oil switch, ASTA tested to BS 2631: 1955. Other equipments shown were 660 V distribution switchboards; motor control and starting gear including a motor-operated rotor starter for slip-ring induction motors; resistors; emergency trip and tappet operated limit switches.

Another interesting feature of the exhibit was a range of hydraulic valves for pressures up to about 3 tons/in² (4·7 kg/mm²) for operation by hand, foot, air cylinder, hydraulic cylinder, or electric solenoid. The special design of these valves includes arrangements to obviate the need for frequent maintenance.

Of the two stands of the **English Electric Co Ltd,** one was occupied by the Diesel Engine Division, and the other by the Welding Equipment Section. The latter stand is dealt with in our review of the Welding Section of the Exhibition on page 109.

Although primarily devoted to diesel engines for marine, industrial, and traction uses, this stand also featured prominently a model of the 500 MW nuclear power station at Hinkley Point which is now being built by the English Electric–Babcock & Wilcox–Taylor Woodrow consortium.

The main engine exhibit was a part of a comprehensive ac marine auxiliary installation for cargo liners and comprised an exhaust turbocharged diesel engine directly coupled to a 350 kW 440 V 3-phase 60 c/s alternator.

Other features of interest were a transparency of the gas turbine installation at the Royal Aircraft Establishment at Bedford, comprising two 20 MW sets—the largest gas turbines yet built by a British manufacturer, and a one-eighth scale working model of an exhaust turbocharged diesel engine directly coupled to a salient pole alternator with an output of 1780 kW.

Garringtons Ltd, who specialize in induction heating equipment, were showing a series of such equipments in the medium and high frequency ranges, together with medium frequency bar heaters, radio frequency hardening equipment, and a representative range of forgings.

The exhibit of the **General Electric Co Ltd** was almost entirely devoted to the comprehensive range of GEC equipment for ships' electrical installations. The major item was a self-excited alternator with an 'Accurex' static regulator providing a

The principal exhibit on the Birlec stand was the newly developed hump-back furnace—a continuous mesh belt conveyor type for the bright annealing and brazing of stainless steel components

* THE BEAMA JOURNAL, 65, No 1, p 4.
† THE BEAMA JOURNAL, 65, No 4, p 149.

supply to motors and fluorescent lighting. This demonstration gave visual evidence of the constant voltage characteristics and the absence of line disturbances with direct-on-line motor starting.

A considerable part of the stand contained a display of modern lighting techniques typical of those incorporated in current GEC ship lighting schemes and also showed examples of lighting fixtures specially designed for these applications.

Shown for the first time on the stand of **Gilbert Gilkes & Gordon Ltd** were the Gilprime multi-stage self-priming pump, the range of Gilkes Centuri electrically operated centrifugal pump units, and the 'Axipel' fullway silent circulator units.

The Ellison 11 kV switchboard with the doors open to show the circuit-breaker and oil switch

This firm manufactures a wide range of self-priming pumps which are available for direct reversing and unidirectional applications; they are supplied as standard equipment to a large number of the leading British marine engine manufacturers.

E. Green & Son Ltd is an old-established firm of economizer manufacturers, and the exhibit included elements of the marine version of the Green's economizer with gilled cast iron sleeves shrunk on to steel tubes and of the aluminium marine economizer.

The main exhibit, however, was the 'Tankerheat' cargo heating system shown for the first time. This consists of cast iron sleeves on mild steel tubes, so combining the advantages of cast iron with the mechanical strength and flexibility of the steel tube.

Pumps were naturally the whole of the exhibit by **Gwynnes Pumps Ltd,** the principal item being a demonstration model of an axial flow pump. Other exhibits consisted of examples from the range of centrifugal, turbine, mixed, and axial flow pumps of all sizes for a great variety of applications.

James Howden & Co Ltd, who specialize in the design and manufacture of equipment for moving and cleaning air and gases, and for transferring heat from one fluid to another, staged a representative display of their products. The principal exhibits included air and gas rotary screen compressors; electro-precipitators for the cleaning of gases; dust collectors for cleaning flue gases; rotary regenerative air preheaters; heat exchangers; mechanical draught fans and exhausters.

Laurence, Scott & Electromotors Ltd, who have supplied four 1225 hp squirrel cage motors to drive the water circulating pumps for the Chapelcross nuclear power station, devoted their exhibit to marine applications and showed two new types of electric cargo winch. One was the 'Selector' dc winch in self-contained form needing no deckhouse accommodation for the contactor gear. The other was a development of the 'Corrector' winch for ac supplies. Now available in 3-ton and 5-ton sizes, it eliminates heavy current surges and requires no deckhouse accommodation other than a small space for the starter.

A variety of interesting applications were to be seen on the stand of **Joseph Lucas Ltd.** The firm's hydrostatic transmission system was demonstrated on a tractor fitted with this one-lever unit, which gives infinitely variable drive from maximum forward to maximum reverse speeds and dispenses with the conventional gear box and clutch.

A pneumatic register was shown which provides rapid remote control of boiler firing equipment, movement of the burner tube and air slide being pneumatically operated by normal service air pressure. There was a range of commercial atomizers covering flows from 0·5 gallon (2·3 l) per hour to 5500 lb (2500 kg) per hour using gas oil or heavy fuel oil, and a boiler torch igniter, either battery, mains, or hand operated, giving a high intensity spark for direct ignition of diesel oil and kerosene.

Describing themselves as 'specialists in specials', **Mawdsley's Ltd** showed a variety of equipment representative of their range of rotating electrical plant for marine and industrial use. Interesting demonstrations were staged of two of their specialities.

The first was the accurate frequency control of a 12 kVA dc driven motor-alternator set using a Mawdsley multicontact bridge type speed governor. This is a centrifugal device capable of controlling the speed to within ±1 per cent. The other demonstration was the consistent stopping of a Mawdsley 'Stop-clutch' ac brake motor in which a combined mechanical clutch and brake unit is operated automatically by the axial thrust produced by the magnetic field. It thus requires no dc for plugging or operation of a magnetic brake and provides close-limit consistency of operation.

Other principal exhibits included a 120 kVA unit construction two-bearing marine type dc driven motor-alternator set; a 75/11 bhp windlass motor with self-contained magnetic disc brake; and a unit construction two-bearing Ward-Leonard set for variable voltage lift together with a lift motor.

Although some of the many exhibits on the large stand of **Metropolitan-Vickers Electrical Co Ltd** were concerned with welding, they will be dealt with here as part of the combined exhibit in the main hall.

A standard Metrovick 50 A atomic hydrogen welder was the principal welding exhibit. The equipment comprises a sheet steel cubicle housing a transformer, reactor, contactor gear, and current tapping switch, together with a welding torch. There are alternative nozzles for the hand welding torch, and such items as a flow control panel and high frequency and surge injector units are also available.

Allied to the welding field was the electric resistance rivet heater, the equipment demonstrated on the stand having three heads for multiple operator use and each capable of heating rivets from $\frac{3}{8}$ by $1\frac{1}{4}$ in (9·5 by 31·7 mm) up to $1\frac{1}{8}$ by 4 in (28·6 by 102 mm) at an average output of 65 lb (30 kg) per hour. Separate transformers are used for each head so that each may be set on a different tapping if more than one size of rivet is required simultaneously and to prevent the loading of one head affecting the heating speeds on the others.

Another interesting equipment was the wire rope parting machine, which parts and seals in one operation any type of stranded wire rope up to $1\frac{1}{8}$ in (28·6 mm) in diameter without preliminary binding. The machine can also be used to seal the individual wires of each strand while leaving the strands themselves separate so that the rope can be spliced.

Other displays featured the firm's X-ray microanalyzer, 'Metroflux' universal crack detector, and the new irradiation service for industry. (THE BEAMA JOURNAL, 65, No 3, p 130.)

Mawdsley multi-contact speed governor for the accurate speed control of dc motors to within ±1 per cent. The dust cover and watertight housing have been removed to show the mechanism

The well-known firm of **C. A. Parsons & Co Ltd** featured only three main items, but all of them of outstanding importance and interest.

The central feature was a one-thirty-second scale model of the world's largest turbogenerator—the 550 MW set ordered

by the CEGB for the new Thorpe Marsh generating station. The equipment consists of two lines in line ahead, each comprising four turbines driving a 275 MW hydrogen and liquid-cooled generator. Steam conditions are 2300 lb/in² (162 kg/cm²) pressure, 1050 deg F (565·6 deg C). Both generators will operate at 18,000 V, 0·8 pf, 50 c/s when driven by the turbines at 3000 rpm. Each rotor is of the direct gas-cooled type operating in hydrogen at 45 lb/in² (3·16 kg/cm²) pressure, and the stator windings are directly cooled by demineralized water circulating through hollow conductors.

Another large turbogenerator represented by a one-twenty-fourth scale model was a 200 MW set—one of two for the West Thurrock generating station of the CEGB.

Each is a single line machine operating at 3000 rpm, with steam at a pressure of 2350 lb/in² (165 kg/cm²) and temperature of 1050 deg F (565·6 deg C) with reheating to 1000 deg F (537·8 deg C). Each generator has a hydrogen and liquid cooling system similar to the 550 MW machine, and is rated at 200 MW, 0·9 pf, generating at 16,500 V 50 c/s.

A third model showed a 100 MW turbogenerator with steam conditions suitable for a nuclear generating station. Because of the maximum gas temperature at the outlet obtainable from a nuclear reactor, the steam conditions are poor compared with those of a modern thermal station, and an improvement in the overall steam cycle efficiency can be obtained by using a dual pressure cycle.

Another exhibit was an animated sectioned model of a gas-cooled graphite-moderated reactor and one of its associated steam generators. Coloured lights indicated the gas flow in the reactor, and coloured fluids the flow of high pressure and low pressure steam and water.

The chief exhibit on the stand of the **Power Plant Co Ltd** was a large double helical colliery winder wheel and pinion standing 13 ft (3·96 m) high. Other examples of the products of this firm of gear specialists included high speed turbine gears; double helical, single helical, and spur gears, and a standard double helical gear unit.

A. Reyrolle & Co Ltd made a special feature of a control-rod head of the type they are supplying for the nuclear reactors at the Bradwell power station. It was a working model and was shown in operation.

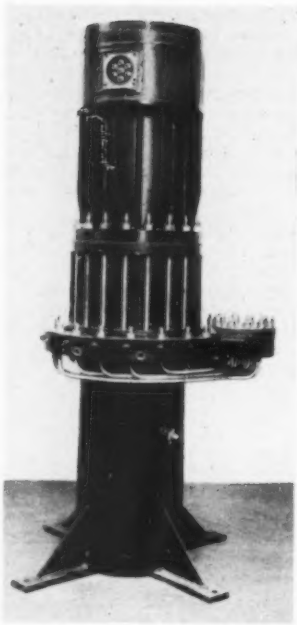
Switchgear exhibits included an 11 kV 200 A 75 MVA oil-break high-speed autorecloser; an 11 kV 100 A oil-break fuse-switch with rewirable type 150 MVA tubular fuses which can also be adapted to take 250 MVA cartridge fuses, and an 11 kV 200 A 150 MVA weatherproof extensible circuit-breaker unit with off-load busbar isolator.

Also on the stand were examples from the firm's range of variable-speed ac commutator motors and welding sets.

The well-known firm of **Richardsons, Westgarth & Co Ltd** specialize in power generation both on land and at sea.

A prominent exhibit was an oil-fired Economic type marine boiler complete with all ancillaries. Propulsion was represented by a marine steam turbine rotor and gearing and various components and models of marine oil engines. Electricity generation was represented by a model of a 117 MW steam turboalternator set.

The Richardsons Westgarth Group makes



A Reyrolle control-rod head as supplied for the Bradwell nuclear power station reactors. The lower cylinder is a pressurized travelling unit to ensure cleanliness during transit

the significant claim to put more horsepower in ships in a year than any other engineering concern in this country or probably in Europe.

Standard Telephones & Cables Ltd devoted their exhibit exclusively to local heating processes for soldering, brazing, hardening, and annealing and showed the latest examples of 'Stanelco' induction resistance and electro-gas heating equipments with special emphasis on the associated handling gear and jigs.

Shown for the first time was a 15 kW high frequency induction heating generator operating in conjunction with a work desk and quench unit, while other equipment on show were 1 kW, 3 kW, and 7 kW generators. All of them have built-in air cooling and variable output transformers for ease of load matching.

An electro-gas heating unit with a one-end loading jig trolley was in operation and carrying out the production brazing of a cam spindle assembly for the door mechanism of Creda electric cookers.

Resistance heating equipment included a completely redesigned horizontally-operating machine with foot-pedal control, available with a 2·5 kVA or 8 kVA multi-tapped transformer, and an air-operated machine available with transformers with ratings up to 10 kVA.

Stewarts and Lloyds Ltd with their associated and subsidiary companies presented a varied range of their steel tubular products.

The bias of the display was towards manipulated pipework and the principal exhibit was a control rod standpipe produced for the Hunterston nuclear power station. Boiler tubes (both seamless and electric resistance welded), jacketed piping, end-to-end welded joints, triform branch reinforcements, a gilled tube coil, rectangular hollow section assemblies, items of ships' equipment and a variety of steel castings were among the other exhibits.

The wide variety of the uses of Tufnol was exemplified on the stand of **Tufnol Ltd** by a representative display of engineering and marine components, including such items as gear wheels, rolling mill bearings, electrical insulators and terminal boards, punchings, and pipe-line coupling flanges.

The material was also shown in several brands in its basic forms of sheet, rod, and tube.

The exhibit by **Wakefield-Dick Industrial Oils Ltd** was designed to show the comprehensive nature of the company's industrial and marine lubrication service.

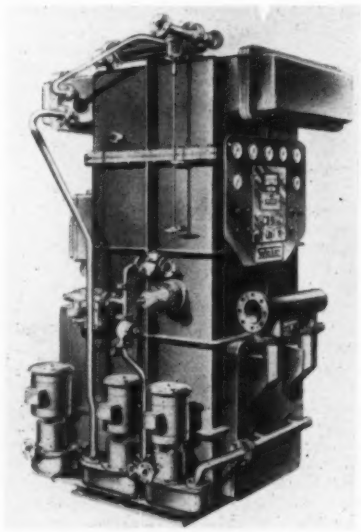
Special emphasis was placed on the part played by the firm's products in the field of electricity generation, and especially on the range of 'Nucleol' radiation-resistant lubricants developed for use with nuclear equipment. Some of the oils in this series have an estimated life, at 10^{11} neutrons/cm²/sec, of between 5 weeks and a year, while the estimated life of some of the greases at the same degree of radiation is between 5 months and 2 years.

G. & J. Weir Ltd exhibited several new designs of marine and boiler auxiliaries.

A diesel starting air compressor which saves up to 25 per cent in space and up to 40 per cent in weight compared with conventional sets of similar performance uses a two-stage design incorporating a rotary/reciprocating motion which reduces the number of piston rings and air valves required.

Another space-saving design on show was the 'packaged' marine evaporator with all the necessary components built in and requiring only steam, water, and electrical connexions. The distillate produced is claimed to be of such high purity that double distillation is unnecessary.

The 'WL' turbo-pump unit has been designed as a lightweight compact machine



The Weir marine evaporator is of 'packaged' design with all the necessary components built in. It can be supplied with outputs of 20, 30, 40, 50, or 75 tons per 24 hours

and comprises a single-stage turbine-driven pump running at 10,000 rpm with water-lubricated journal bearings.

Mention must also be made of the model of the 'Multiflash' sea water distillation plant recently ordered by the States of Guernsey, Channel Islands (THE BEAMA JOURNAL, **65**, No 4, p 157).

The stand of the **Westinghouse Brake and Signal Co Ltd** was devoted to the company's marine activities in the pneumatic control field and included such equipment as a controllable pitch propeller and a mock-up of a marine engine and gear box controlled from a dummy bridge.

Worthington-Simpson Ltd had a representative selection of centrifugal, steam, and marine pumps, as well as rotary and 'Monobloc' air compressors and a marine condensing plant complete with inter- and after-cooler, ejector, and extraction pump. One of the 'Monobloc' pumps featured the new Worthington-Simpson flameproof motor enclosure. The latter are built in sizes ranging from 1 to 7·5 hp at 1450 rpm and 1·5 to 12·5 hp at 2900 rpm and are certified for use in the presence of inflammable gases or liquids. They carry Buxton Certificate Nos 4030-4035 for groups I and II gases.

The maximum capacities of the pumps exhibited were 3900 gallons (17,700 l) per minute with heads up to 600 ft (183 m).

One of the most ingenious stands was that of **Yorkshire Imperial Metals Ltd,** designed and built by themselves and roofed with gleaming copper tubes. From the electrical point of view, the most interesting exhibit was the display of hollow copper conductors now in increasing demand for direct-cooled windings of turboalternators, cyclotrons, magnet coils for nuclear research, transformers and other electrical equipment where rapid heat dissipation is important.

The firm has done considerable development work on these conductors and can now supply them in square or rectangular sections, sections with round or elliptical bores or other types of unusual hollow sections, with walls of uniform or varying thickness.

The Welding Section

Among the new developments shown by the **Arc Manufacturing Co Ltd** was a contour-following device by which welded joints of irregular profile can be made without repositioning the work. The path of the welding head, to which an argon-arc torch is fitted, is governed by a fixed template which corresponds with the contour of the joint to be welded. The 'Arcontour' machine will accommodate the welding of seams at angles of more than 30° from the horizontal, maintaining a constant wire feed and producing the same weld profile regardless of the welding angles at which the work may be positioned.

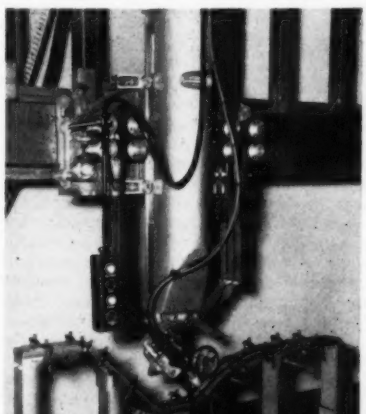
The company has also designed (primarily for the tungsten inert-gas welding of stainless steel, nimonic, titanium, copper, nickel, etc) a new range of welding rectifiers, with varying capacities from 40 A to 250 A. These units, which can also be used with coated electrodes for welding mild and low alloy steels, bronze or aluminium, are oil-cooled, so ensuring freedom from contamination or disturbance of the atmosphere by fans and at the same time affording certain mechanical protection. The units are rated for continuous welding using dc, and there is remotely controlled semi-automation of a number of the operations involved.

There was also demonstrated a method for resistance heating a 12 in (305 mm) diameter pipe to a pre-heating temperature before welding, followed by an annealing temperature of 650 deg C after welding. The power source is a 'Masta' transformer with a maximum output of 440 A and two voltage ranges: 65 V over a current range of 70-440 A and 95 V over a current range of 50-300 A.

A section of the stand of British Federal Welder and Machine Co Ltd showing a number of their standard machines. Suspended above the stand is a typical car underbody produced on a completely automatic production line supplied by the company

During the past year the **British Federal Welder and Machine Co Ltd** has completed a large special-purpose installation for a leading British motor-car body manufacturer, and this aspect of the company's activities was displayed in a number of examples of specialized equipment including fully automatic production lines capable of producing up to 120 assemblies an hour of components such as doors and underbodies; automatic conveyor-fed, hopper-fed, and magazine-fed projection welding equipment.

Another aspect of the stand emphasized



The welding head of the 'Arcontour' argon-arc welding machine by Arc Manufacturing Co Ltd. Photograph shows the workpiece suitably jigged, with the torch inclined above the electrode tip to keep it normal to the contoured work surface

the new range of the more standard types of resistance welding equipment from small bench type models to large seam and multi-spot welders. Among the latter was a model of a fully automatic drum forming and welding equipment for the high-speed production of drum shells.

Other notable exhibits in a display full of interest were an upsetting machine capable of mushrooming the end of a $\frac{3}{8}$ in (9·5 mm) diameter metal bar in 10 seconds, and the firm's patented 'kickless' welding cable which not only eliminates the objectionable 'kick' associated with portable welding equipment but provides an overall improvement in power factor and a reduction in cable losses.

Among the exhibits of **Electro Mechan-Heat Ltd** was a 5 kVA portable butt-welding machine equipped with a self-contained compressor unit which enables the machine to be moved from point to point in a workshop.

A new machine was a high-speed air-operated spot welder capable of rates up to 1000 spots a minute. It has a high-lift cylinder and built-in air reservoir, and its high speed is achieved by a specially designed electronic control unit.

Three standard electronic timers, a standard ignition panel assembly for machine mounting, and an ignition assembly for wall mounting were also shown.

Mention should be made of a new machine recently developed by this company for automatically welding the mains plug socket to the resistance element of ordinary domestic irons. A 3-stage timer deals with the welding operation and a single-stage timer controls work-table functions. An automatic 1500 V flash test is included in the system to check each assembly before it leaves the machine.

On their stand in this section, the **English Electric Co Ltd** showed a very large range of equipment which included two completely new types.

The LWAD 500 is the first oil-cooled portable rectifier equipment incorporating silicon rectifiers to be placed on the British market and is one of the most advanced designs in portable equipment. It offers a choice of two outputs: 95 to 520 A dc of either polarity or 116 V 624 A ac which are selected by a 3-position switch. The other new type also shown for the first time is the LWC 2/300 double-operator portable welding equipment giving two outputs each of

34 V 315 A or one output of 34 to 630 A if a heavy welding current is required. This is achieved by a simple device which parallels the two outputs. This is also a neat and compact equipment and a special feature is the built-in power factor correction.

Another recent introduction is the LWD 350 portable rectifier equipment with an infinitely variable output over the dc range of 34 to 315 A. It incorporates fan-cooled selenium rectifiers and is designed for operation on 380 to 440 V 3-phase 50 c/s supplies, taking a balanced load from the mains.

Holden & Hunt Ltd staged what was perhaps the biggest concentration of resistance welding and heating machines in the Exhibition.

To begin with, there were five universal pedal-operated spot-welding machines of 5 to 10, 15 to 25, and 40 kVA capacities, together with a complementary range of air-operated spot welders of similar ratings. The latter can be used for single spot and variable speed repeating operations. Both ranges were presented with a variety of arm and electrode arrangements.

Next, four auto-wire butt welders rated from 3 to 30 kVA were available for demonstration with differing clamping controls. Two flash butt welders were typical of a range of five different sizes, the Nos 4 and 5 on the stand having welding capacities of 0·3 and 1·0 sq in (194 and 645 mm²) respectively.

One of the 21 machines shown on the stand of Holden & Hunt Ltd. This is a 15 kVA universal air-operated rocker arm machine designed for both single spot and adjustable stitch welding sequences

Single, twin, and triple head rivet heating machines were shown, with ratings from 6 to 30 kW and capable of heating rivets from 0·25 by 0·5 in (6·35 by 12·7 mm) up to 1·0 by 6 in (25·4 by 152 mm).

Sliding head machines were represented by a 25 kVA spot welder (the smallest of this range) which can be used either as a single spot or a stitch welder and a 200 kVA projection welder.

A last-minute arrival on the stand of the **Lincoln Electric Co Ltd** was a completely new silicon rectifier-transformer for arc welding stated to be the first of its kind to be made in Great Britain. Among the special features claimed for it are: good performance for difficult positional welding or where deep penetration is required; particularly suitable for low hydrogen electrodes and the low chrome alloys; high open circuit voltage of 90 V; stepless current control; wide current range from 60 to 300 A in two stages.

The exhibit as a whole was designed to portray the firm's ability to provide an extensive submerged arc welding service. The first noteworthy item was a complete range of fused and unfused fluxes for both mild steel and hard surfacing, together with alloy fluxes for the welding of 12 to 14 per cent chromium stainless iron, 18/8 austenitic steels, including niobium-bearing and molybdenum-bearing; molybdenum-bearing and chrome-molybdenum creep resisting steels.

From the firm's range of submerged-arc welding machines for every application, the following equipment was shown.

The new Lincoln twin head tractor for submerged-arc automatic welding specially designed to speed production of fillet welding in the shipbuilding and kindred industries. This equipment, which is interchangeable with existing units, retains the advantages of the standard Lincoln tractor and has several additional features.

The Type B 10 fully automatic submerged arc-welding head was shown mounted on a retractable column and boom, suitable for both the internal and external welding of vessels and pipes of all sizes, thicknesses, and diameters. All types of fabrication can be welded with this machine, as the head is designed to give localized horizontal movement in all directions and vertical lift between 6 in (152 mm) and 28 in (71 cm) as required.

The manual Lincolnweld type M L 3 submerged-arc welding unit is a development of the basic M L 2 incorporating a new remote control unit. This gives full control of the welding currents and voltages and its compactness allows the unit to be taken into confined spaces. Three alternative power sources are available. These are the SAE 600 motor generator, delivering continuously 420 A for automatic welding, but capable of providing 600 A for continuous hand welding; the SEA 900 motor generator delivering continuously 630 A for automatic welding, or 900 A for continuous hand welding; the C V 750 constant potential unit, delivering continuously 750 A for automatic welding.

In the field of manual arc welding, the firm showed a complete range of generators, transformers, and rectifiers; iron powder, mild steel, and alloy electrodes; the 'Arcair' cutting and gouging process; accessories and protective clothing.

Quasi-Arc Ltd showed several new developments in both manual and automatic arc welding. One of these—the equipment for vertical Unionmelt welding—was the first of its kind to be made in Great Britain and a production version will shortly be available.

The process involves the formation of a molten pool between the edges of the vertical plates to be welded, the sides of the pool being retained by copper dams. The molten pool is fed by the normal type of Unionmelt submerged-arc welding electrode and flux composition, and the welding head and copper dams are raised progressively as the

The 'Arcmaker' silicon rectifier-transformer for arc welding shown by Lincoln Electric Co Ltd. It is rated at 250 A at 35 V continuously or 300 A for intermittent use

level of the weld rises. The weld metal solidifies before it emerges below the bottom edge of the dam and the pool is protected from contamination by a layer of molten flux powder. All the variables in the process are controlled automatically and the resulting weld is stated to be of good X-ray quality.

Another new introduction was a self-propelled twin-fillet welding machine, the first three of which have been supplied to the Furness Shipbuilding Co Ltd, who are using them to weld stiffeners to the bulkhead panels of large oil tankers.

The machine, which is fitted with two CO_2 automatic welding heads, can make twin horizontal-vertical fillet welds simultaneously and can traverse at speeds between 12 in (30·5 cm) and 36 in (91 cm) per minute. Its maximum welding speed (which can be pre-set) is about 26 in (66 cm) per minute.

An important feature of the new machine is its self-guiding action, by which the welding heads are automatically aligned to the stiffener webs and follow them accurately, even when there is waviness in the horizontal or vertical plates. It can readily be adapted for use with the Unionmelt submerged-arc process, and a similar design of machine can incorporate welding heads for the inert-gas-shielded welding of aluminium.

Examples of another new development—the Quasi-Arc 'basic welding head'—were shown and demonstrated. Among them was the Fusarc/Co_2 pistol welder, an equipment incorporating the basic head and designed for semi-automatic welding applications. It combines the advantages of the Fusarc/Co_2 automatic welding process with the flexibility of a hand-operated welding gun.

In the range of manual welding electrodes, a new one—Ferron No 3—was shown for the first time. It has been designed specific-

ally for the atomic energy industry, but lends itself to many other applications where high impact strengths at low temperatures are required.

Advances in welding power supply equipment were represented by two new motor-generator sets and a 'plug-in' rectifier which can be used with any Quasi-Arc single-operator transformer set at open-circuit voltages up to 80 V.

Several new features appear on the stand of **Rockweld Ltd.** Shown for the first time was a production fillet welder—an original development believed by the firm to be the only equipment of its kind in the world.

The welding head is mounted on a pair of hinged arms, with suitable linkages and counter-balances, to allow the welding nozzle to be instantly applied to a horizontal-vertical fillet joint over a fairly wide range of positions. The welding nozzle follows the line of the weld automatically even if there is a horizontal and vertical misalignment—which may amount to several inches—between the track of the carriage and the workpiece.

The model shown on the stand was equipped to make only a single weld. Another version of the same machine, however, will enable simultaneous double fillets to be made on each side of the vertical plate. The equipment is mounted on a trolley which traverses an Autopak type bridge boom 30 ft (9·14 m) in length.

Another important exhibit was the Autopak arc welding equipment. Rockweld believe that this could be the first step towards the welding transfer line, since its system of control for the welding head and the carriage is particularly adaptable to the realization of automation in the fabrication shop.

The Autopak is a versatile unit incorporating a new conception in automatic arc voltage control which is more sensitive than existing methods, although the Autopak is a robust machine, free from costly elaborations, portable, and easy to maintain and operate. When not fully employed in making automatic submerged-arc welds, it is available for hand welding with ordinary coated electrodes.

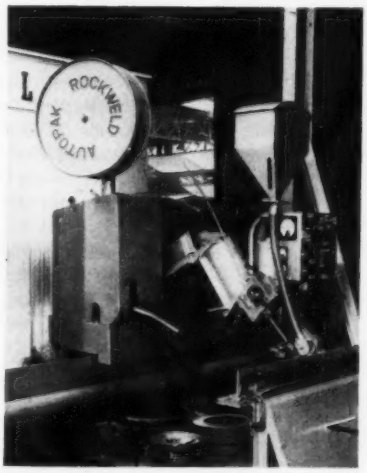
Its uses have been considerably extended by the addition of a boom mounting for the self-propelled carriage. This is 20 ft (6·1 m) long and can be mounted at varying heights on a wheeled 'A' frame, enabling the equipment to make butt, fillet, and lap welds up to 17·5 ft (5·33 m) long at any desired height above floor level.

Another interesting demonstration was the Rockweld carbon dioxide welding process known as the Comet Process. In this an arc is struck between a special composite continuous wire and the workpiece in an atmosphere of carbon dioxide gas. The wire contains the deoxidizing agents and the slag-forming materials; the carbon dioxide protects the metal from atmospheric contamination during transfer and in the weld pool. It is, therefore, a visible arc process and readily adaptable for both automatic and semi-automatic operation.

The equipment is based on the Autopak power source and welding head. The head can be either mounted on a carriage with the wire fed directly to the carbon dioxide nozzle, or it can be used in conjunction with a flexible feed tube and a gun. The carbon dioxide used is normal cylinder gas fed through a pre-heater to a pressure regulator and flow-meter, and introduced round the arc by means of an annular copper nozzle. The composite wire used in this process is fabricated from steel strip and is not in the form of a tube. It contains its own flux and ionizers which improve the stability of the arc and, in particular, enable it to operate on ac. The slag-forming elements help to reduce spatter, shape the weld, and give the necessary metallurgical quality in the weld deposit.

The Vertomatic automatic vertical slag-welding machine is manufactured according to patents held by Vus (Bratislava), for which Rockweld are the sole licensees in Great Britain. It was shown and demonstrated for the first time at this exhibition.

The Rockweld-Vus Vertomatic equipment provides considerable economies in heavy fabrication welding in plate thicknesses of 2 in (50·8 mm) and upwards, because of the elimination of plate preparation and the associated smaller quantity of weld metal required; the elimination of multiple



The Rockweld 'Autopak' production fillet welder showing the articulated arms which allow the welding head to follow the contour of the workpiece. All the controls for welding and for the automatic carriage traverse are mounted on the welding head

passes with associated deslagging and chipping; the economy in flux powders; and the high thermal efficiency of the process, resulting in low energy consumption.

Sciaky Electric Welding Machines Ltd showed several new resistance welding machines with varied examples of assemblies welded by the Sciaky three-phase and 'Modu-wave' systems. The three-phase system of which Sciaky are pioneers offers the advantages of high power factor, balanced load on all 3 phases, 'tailor-made' secondary wave slope, extended electrode life, and a wider application in weldable materials. The 'Modu-wave' system has particular advantages for welding highly stressed structural assemblies and for critical welding operations, and a noteworthy example was afforded by part of the fuselage of a Victor jet bomber, which has altogether 550,000 spot welds in its class I structure.

The 'Rapid' spot welders represented a new range of air-operated all-purpose machines of 15, 25, and 50 kVA ratings with optional throat dimensions from 12 to 36 in (30·5 to 91·4 cm). They are capable of stitch welding speeds up to 250 fully controlled spots per minute.

Another new range consisted of heavy duty machines of 75 kVA nominal rating and upwards. Special features are the four-channel electronic timer which is directly interchangeable with any other modern Sciaky spot welder, and extremely good vertical height adjustment, as the bottom arm is attached directly to a tee-slotted main frame and has arm adjustment afforded by the hydraulic jack fitted as standard equipment.

One of the new streamlined projection welders of the Speedforge range, a 300 kVA model, was shown; other machines in this group are 40, 75, 150, 500, and 600 kVA units. This welder is also electronically controlled with the standard thyratron unit fitted to the spot welders, and phase shift heat control, thermostat ignitrons for primary current switching, and a slide type head for low-inertia stroke action are notable points.

The latest Sciaky product is the small precision spot welding machine type BSF 1 Mark 2. This has been designed and manufactured for work in instrument and electronic valve production plants, etc, where a high degree of precision is required. A minimum weld time of $\frac{1}{2}$ cycle can be achieved, and the fully synchronous dekatron timer also incorporates an electronic phase-shifting device for vernier adjustment of welding heat. An electrode force of only a few ounces can be applied and the in-line head is extremely speedy, ensuring that the electrodes are in constant contact with the workpieces. The welding head, transformer, timing control, and phase-shift device are integrally mounted to a work bench equipped with a Formica top.

Mention should also be made of the Sciaky School of Welding which operates a five-day course and caters for welding personnel from Great Britain and from overseas. A syllabus describing the nature of the instruction is available on request.

Solus-Schall Ltd showed a comprehensive range of the non-destructive testing equipment in which they specialize. The techniques included X-ray and gamma-ray, magnetic crack detection, ultrasonic and eddy current equipment, X-ray crystallography, penetrants and magnetic inks.

Among the new equipment were an automatic ultrasonic flaw detector for thicker welds from 1 to 7 in (25·4 to 178 mm), and an automatic recording flaw detector for longitudinal welds, shown with a photographic recorder in position so that both visual and photographic inspection could be made of the cathode-ray trace which indicated the flaw echo in a specimen.

Other exhibits were a processing unit for the continuous examination of both metallic and non-metallic articles for surface cracks by means of fluorescent penetrants; the 'Junior' crack detection unit—a new and relatively small magnetization unit for the inspection of ferrous components by means of magnetic ink, and an X-ray unit for two-tube operation in connexion with crystallographic examination.

It should also be noted that the company operates a complete site and laboratory inspection service employing all methods of non-destructive testing.

'Electricity and its Contribution to the Standard of Living'

This was the theme of the Eleventh British Electrical Power Convention *held during the first week in June and attended by about 1000 delegates from all parts of the United Kingdom, representing between them the 40 principal organizations connected with the British Electrical Industry.*

The President of the Convention was Mr C. R. King, CBE, COMP IEE, M INST F, *Deputy-Chairman of the Central Electricity Generating Board.*

First Session: The Presidential Address

MR KING began by tracing the earliest beginnings of the electricity supply industry, because he felt that many people outside the industry were quite ignorant of them.

Starting with 1919, the year in which he joined the industry, he pointed out that at that period the larger cities and municipalities had electricity supply undertakings, but supplies were very restricted in character and mainly to shops and business premises within the boundaries of the cities and boroughs. Industrialists did not willingly forsake their tried and proved methods of power production for public supplies of electricity which were then notoriously unreliable.

The Formative Years

The first ten years after World War I saw the industry make tremendous strides.

The rapid developments in electricity supply during the early 1920s led to the establishment in 1926 of the Central Electricity Board who were charged with the dual task of seeing that large and efficient generating stations were provided and that these were linked by extra-high tension transmission lines. They had the power to 'select' existing generating stations and to authorize the building of new ones which were labelled 'Super Power Stations' and generally had a capacity of less than 200 MW.

The inception of the CEB gave a tremendous impetus to the development of electricity supplies, especially in areas—and there were many—which hitherto had had no public supplies of electricity of any kind. Large industrial concerns were given much more security against possible interruptions in the supplies they required. As efficiency improved, prices became lower and lower, and by 1939 the country as a whole had a cheap and abundant supply of electricity.

'And it was well for the nation that it was so,' said Mr King, 'because World War II was upon us and our great industry was to be tested in a way which not one of those early pioneers could have visualized; tested not only with the hazards of war but with the Industry's ability to cope with major industrial developments of vital importance to the war effort.

'The growth of load, generally speaking, had to be met from existing plant capacity because neither money, materials, nor manpower could be spared for the building of new generating stations at a rate which would have kept pace with the demand. Thus the end of the war found the Industry stretched almost to breaking point both in generating plant and distribution networks, and it is true to say to-day, fourteen years later, that the distribution systems of the country have never fully recovered despite the vast amount of capital spent in these years.'

In 1948 the supply industry was nationalized, and Mr King next dealt with some of the problems facing the newly-constituted Central Electricity Authority:

'Perhaps the most important problem was the merging together of some 540 undertakings, municipal and company, into the fourteen Area Boards, and the welding together of the staff and employees of those undertakings.

'Undoubtedly the biggest single problem which was inherited by the British Electricity Authority was the shortage of generating plant and main transmission lines. It is sufficient to record here that this problem was tackled vigorously and, within the limits of the capital which the Government of the day felt could be spared, new generating stations and transmission lines were planned and ordered.

'Even so, load shedding in a fairly substantial way had to be resorted to during the first seven years after the Industry was nationalized. It should be remembered that the orders which the Central Authority were anxious to place exceeded the output of the manufacturing industry in turbines, generators, boilers, etc, and that, but for the whole-hearted cooperation of the manufacturers, load shedding and voltage reduction might have become a regular feature of the Industry during the winter months.'

Then came the Electricity Act of 1957, which abolished the Central Electricity Authority and in its place set up the present Electricity Council and the Central Electricity Generating Board. Of the new and difficult problems confronting the latter body, Mr King had this to say:

'First of all there was the inherited programme of new generating stations, both thermal and nuclear. Because of the increase in the capacity of new generating stations and the steady but pronounced increase in the size of individual units, it was expected that the future requirements of the entire Industry could and would be met by providing four new generating stations each year, two of which would be nuclear. This was instead of the seven or eight which was the average number of new stations commissioned by the Central Authority each year.

'The second big problem facing the Generating Board was that of the bulk supply tariff. The Generating Board decided to put forward a new bulk supply tariff for 1959/60 containing an increased kilowatt charge and a correspondingly reduced unit charge. Thus every possible incentive would be given to the Area Boards to improve

the national load factor by offering attractive tariffs for night and off-peak loads.

'A third problem which is already causing the Generating Board considerable concern is the extensions necessary to the present transmission system and the siting of new lines. Work is still in progress on the planned 275 kV grid, but the rapid growth of generating capacity to deal with the ever-increasing load makes it essential for the existing grid lines to be adequately reinforced.

'A partial solution of the problem may be found after an early investigation into the possibility of stepping up the voltage of main transmission lines to 380 kV or even 400 kV. This would add very considerably to the carrying capacity of future main transmission lines and especially those provided to transmit current from the new nuclear stations.'

The Industry's Contribution

'This survey does in broad terms indicate how we have contributed to the better living which is enjoyed by practically everybody to-day compared with forty years ago.

'With the advent of the nuclear power programme which has raised our prestige in the eyes of the whole world; with the expectation that generating costs at future nuclear stations will be at least no more than the present costs at conventional stations and possibly less, we should make tremendous strides during the next decade or two in providing cheap and abundant supplies of electricity for all the manifold purposes which affect the daily lives of the people living in these Islands.

'In the early 1930s only one house in three had a supply of electricity, and more often than not it was used for lighting purposes only. To-day electricity is a "must" with everyone.

'The average price of electricity to the domestic user has only risen by some 35 per cent since 1948, and during those eleven years wages generally have been nearly doubled. Obviously, therefore, the householder who keeps a careful budget can afford to set aside the same proportion of his weekly earnings to-day as in the past in order to purchase something like three or four times as much electricity as he was accustomed to using eleven years ago.

'Manufacturers will, I am sure, agree that the measure of their export business depends to a great extent upon their home sales. The Supply Industry has developed its business and the manufacturers have kept pace with these developments by providing all the turbines, boilers, generators, cables, transformers, switchgear, domestic appliances, etc. They have developed a substantial export business. For the third year in succession the direct exports of the Industry have exceeded £270 million, which figure compares with a figure of £25 million in 1938 when Great Britain was the world's largest exporter of electrical goods. This contribution to the nation's balance of trade has enabled the country to buy abroad the raw materials and food which we cannot produce here.

'So long as the nation maintains its position in the markets of the world and productivity at home continues to increase, the future livelihood and prosperity of the individual workers at home is assured. The united efforts of all branches of our great and thriving industry will be necessary to meet the demands which will be made upon us in the years which lie ahead.'

Second Session: Progress on the first Nuclear Power Stations—Bradwell, Berkeley, Hinkley Point, and Hunterston

F. H. S. Brown, BSc, MI Mech E, MIEE (Full-time Member, Central Electricity Generating Board)

and

J. Henderson, MC, BSc, ARTC, MIEE (Chief Engineer, South of Scotland Electricity Board)

The presentation of this paper to the Convention was made jointly by the two authors and consisted largely of the showing of a series of plans and photographs illustrating the constructional progress of the four stations, while the printed paper dealt mainly with a description of the basic design of each station and showed how the heavy engineering work required to translate these designs into working entities was planned and executed.

Some general points of considerable interest were made by the authors, of which the following is a summary:

'The design of a nuclear station must be such that not only does the final result form a coherent workable and economic generating unit but also such that the station can be constructed rapidly and economically.

'Not only are capital costs reduced by a design which permits a logical sequence of construction, but the money expended in construction is not productive until the station becomes operational; since nuclear stations of the type here discussed will have a total cost of between £40 million and £70 million each, the capital charges towards the end of the construction period will be over £250,000 per month per station, and therefore every month in which non-productive costs can be replaced by revenue earning generation is of the utmost significance.

'Nuclear stations are saddled with very high capital costs, and although the running costs are relatively low the present stations will require to run at load factors approaching 85 per cent in order to be economic. Coal burning stations normally operate at such high load factors only for a few years before being superseded by more efficient and higher merit stations as these are commissioned.

'This picture does not hold in the case of nuclear stations. The first four stations have been designed to burn natural uranium which for many years to come must continue to be the cheapest form of natural fuel. The incremental cost of operating the present stations is thus inherently low, in fact lower than any coal fired station is likely to attain, and once the capital has been spent it follows that they should operate at high load factors throughout their lives.

'As the incremental cost is low and any improvement will become more and more marginal, the general direction of advance in the design of nuclear stations will be aimed at reducing the capital cost with a minimum advance in fuel cost. This is necessary since clearly there is a limit to the amount of plant which can be installed on the British systems to be economic only on base load. When this limit is reached then further nuclear plant can only be installed which is economic at lower load factors, and this, in turn, must depend on reduction in capital cost even at the expense of an increase in fuel cost. It may be that when plutonium has been proved as a commercial fuel the more advanced stations will themselves show a reduction in fuel cost, but such a development is unlikely to reach fruition early enough to affect the running of the present stations.

'Future developments therefore in electricity generation indicate that the earlier and more expensive stations will continue to be run at high load factor during their financial lives, partly because having made the capital investment it is economic to do so in view of their low incremental fuel cost, and partly as plutonium producers to provide the fuel for later stations of a different type, with lower capital costs which will therefore be economic at lower load factors.'

Third Session: 'Priority No. 1'

A. N. Irens, MSc, DFH, MIEE, M Amer IEE (Chairman, South Western Electricity Board)

The author defined his paper in the sub-title as 'The provision of a reliable supply of electricity at a constant voltage and at the lowest possible price to all who want it'.

The complete paper was a lengthy one, discussing a very wide field in considerable detail and supported by numerous statistical tables and charts. Mr Irens therefore presented his paper in a speech which summarized his chosen subject. Here are his principal points.

'Industry and commerce are now, and will continue to be, our first line of defence and on their success will depend the rate at which our way of life can advance. Behind British commerce and industry, as its first servant, stands the electrical industry, without which industry as we know it to-day, from production to marketing, could not exist and cannot hope to develop. And, moreover, each decade will see the dependence of commerce and industry on electrical power grow more far-reaching, more complete.

'Electricity, with its unique capacity to distribute virtually unlimited power from every kind of source, where and in what form we want it, cheaply and easily, is the key to almost everything, in the material sense, that mankind wants to-day.

'One has only to look about the world to see how every major country is grasping this truth. We are accustomed to think of such countries as Switzerland, Sweden, the USA, and Canada as electrically advanced, but the same drive is at work in Australia, Russia, India, China, and in the great countries of South America where populations have recently been expanding about two and a half times as fast as the rest of the world.

'We must expect that not a few of the industries these countries are so vigorously developing with the aid of electric power will pass, in our lifetime, from their home markets to the world export trade. We shall have to meet steadily increasing competition not only in their home markets but in our accustomed markets elsewhere.

'Our answer, as one of the world's pioneer industrial nations, is to keep one jump ahead. We have sold our brains and our genius for management all over the world for more than a century on the grand scale and there is every reason to expect that an industrialized world will need what we have to offer more, not less, as the years go by. We shall only do this if the electrical industry, on which modern machine-age industry rests, and on which its development so conspicuously depends, is kept constantly advancing; constantly in a position, not only to meet, but to anticipate with intelligence every demand which industry and the social consumer, public and private, is going to make.

'Electricity, nowadays, is often the cheapest form of labour. But it is much more than that; it is the means by which we are progressively shifting the emphasis, in office and factory, from muscle-power to mind-power. Electricity is taking more and more of the dirty jobs, the dangerous jobs, and the drudgery out of the hands of men and women. This is a social gain, and a great one; it will prove to be an economic gain as well.

'Automation will also make increasing demands on our electrical resources. The corollary, for the electricity industry, is that automation will demand from us that supplies shall be not only adequate and cheap, but as nearly absolutely dependable as ingenuity can make them.

'Another corollary to automation is the development of round-the-clock working to make installations economic. This, in turn, may be expected to lead to the development of control systems which will minimise night-work and concentrate the human contribution as far as possible within socially acceptable hours which allow a full and normal family life. On the non-industrial side the demands are no less far-reaching.

'What is required to ensure that these pressing needs can be met? It means, in the first place, that the electrical industry should attract a larger share of the nation's development capital. The present proportion is about 8 per cent—a figure which surely is unrealistic for a key industry. Moreover, as more and more factories come on the mains instead of doing their own generation, capital costs hitherto borne by industry are being shifted to the supply industry—an added reason why capital for development needs to be increased.

'Not only do we need more capital; we need to be able to count on continuing to get it. In an industry such as ours in which it may take as long as five years to pass a project through all its many stages, continuity is the very essence of planning.

'I would go so far as to say that we should have a slogan, "Invest in Electricity", which applies not only to our supply industry but to the users of electrical energy. Habits and fashion may change, but if there is one safe bet in this world it is to "Invest in Electricity".

'As an industry, we have nothing to hide and a great

deal to be proud about. If we can be given the relatively modest extra capital we need to keep the pipe-lines full and flowing, and the continuity of financial policy that allows for steady growth, I am confident that the next ten years could put this country right where it needs to be—in the van of the electrical age.'

Opening the discussion, Mr S. F. Steward, Director of the BEAMA, began with a tribute to the achievements of the Board of which Mr Irens is Chairman.

'The South Western Electricity Board have made a great contribution to the well-being and prosperity of the West Country,' said Mr Steward. 'Since 1948 the units sold annually by the South Western Board have increased nearly three times. A quarter of a million new consumers have been connected to the mains, and more than three times as many West Country farms now enjoy the benefits of electricity.

'A major factor has been the Board's outstanding success in selling domestic electrical appliances. Their annual sales have now reached a figure of £4 : 8s per consumer—probably the highest in the country.'

Mr Steward characterized the progress and achievements of the supply industry described in the paper as one of the great success stories of our day. 'We now have the situation in this country that 93 of every 100 premises can enjoy all the benefits of electricity at prices which, by any standards of comparison with other goods and services, are very cheap indeed,' he said.

Mr Steward continued: 'Speaking from the viewpoint of the manufacturers, I can say that the supply side has served us well, and that great credit is due to all who have made this success story possible. . . . There is a very real partnership and understanding between the nationalized supply and the private enterprise manufacturing sides of our industry—a partnership which has proved a great source of strength to the industry and the country.

'The paper gives many examples of this. One is the steady improvement in the efficiency of generation, resulting in a saving of 40 million tons of coal. This has been achieved by improvements in design, with larger units and higher steam pressures and temperatures. Distribution transformer losses have been significantly reduced as a result of design and manufacturing improvements. This has proved of great benefit in extending rural supplies, particularly as the price per kVA has been reduced despite increases in costs of labour and material.

'Advances in the design of domestic appliances and the introduction of new appliances have greatly stimulated domestic load development.'

Mr Steward said that he believed that the greatest single contribution to the improvement of load factor and to the effective use of the growing capital investments of the industry was to plan for a really full exploitation of the domestic load. 'So far we have only touched the fringe of it,' he declared.

Looking at the proportion of electricity consumers who were not yet getting the full benefit from the electricity service available to them, he pointed out that out of every 100 consumers, 71 had no electric cookers, 69 had no electric water heaters, 74 had no washing machine—and nearly 90 were managing, somehow, without an electric refrigerator. This was a measure of the market to go for and of the magnitude of the service the industry still had to render. He concluded:

'A combined effort, with every section of the industry playing its part, would put domestic electrification really on the map. In the BEAMA we have just established a Domestic Division, with its own Board, in recognition of the importance of the domestic side of our industry, and this is a body with considerable influence and authority which I am sure would cooperate wholeheartedly with the Electrical Development Association in any efforts designed to foster the development and expansion of the domestic load.

'I hope that we can find a means of doing this, as I am sure that in a vigorous, live, and expanding industry such as ours, boldness and commercial enterprise will pay great dividends.'

Fourth Session: 'The Scope of Installation Engineering'

C. C. Hyams, MM (President, Electrical Contractors and Allied Associations)

'National Inspection Council for Electrical Installation Contracting—Its Objects and Organization'

E. J. Sutton, MIEE (Chief Technical Officer, NICEIC)

Mr Hyams started by making the point that the installation engineer has been a key figure in the electrical industry from the very beginning; his value is based on his practical knowledge and experience, and while he does not in any way usurp the function of the electrical consultant, he necessarily acts as such in many installations where the services of a consulting engineer would not be justified.

Mr Hyams then briefly discussed six factors which affect the design of an installation and which the contractor must continually consider: adequacy, flexibility, safety, materials, economics, and convenience, and continued with a detailed consideration of installation work in six broad divisions: ships' installations, industrial installations, commercial and public buildings, agricultural installations, domestic installations, and overseas installations.

In each of these six fields, Mr Hyams examined closely the scope of the responsibilities resting on the installation engineer and the services he renders to the user, putting a special emphasis on a regular system of inspection and maintenance of the completed installation.

In dealing with the overseas field, Mr Hyams made these points:

'The problems associated with the electrical installation industry at home are many and varied. Because of this and the diversification of the operations involved, it is even more difficult to carry out such work abroad. In spite of this, British electrical contractors have been responsible for a very large volume of overseas work and

for the training and instruction of tradesmen in many areas of the world.

'Most overseas contracts require a profound and comprehensive appreciation of electrical engineering, with a knowledge of overseas standards in addition to those of the Institution of Electrical Engineers. Many countries of the world work to their own regulations, which may be a mixture of some local engineer's ideas together with those of the IEE, often with parts on the American or Canadian national codes. One has to be conversant with foreign equipment or equipment specially designed to suit local conditions.

'Members of the British Electrical Contractors' Association have carried their skill to the far ends of the earth, to Africa, the Middle East, the Far East, the West Indies, and to the less remote places such as the countries of Europe. In all cases they have acquitted themselves well, leaving a knowledge of their skill, the high standards of the Institution's Regulations and British workmanship firmly implanted in the life of those countries where they have plied their highly skilled and complicated trade.'

Mr Sutton's paper opened with a brief survey of the history of 'safe wiring', from the first edition of the Wiring Regulations in 1882 to the latest amended thirteenth edition of 1958. He then dealt with the formation in 1923 of the original National Register of Installation Contractors, leading to the establishment in 1956 of the present body as an independent non-profit making organization with the primary object of protecting the electricity consumer against faulty or unsafe installations.

The rest of Mr Sutton's paper described in detail the operations of the Council, followed by a review of its progress during the first two years of its operation.

Fifth Session: 'Lighting and the Common Weal'

O. W. Humphreys, CBE, BSc, MIEE, F Inst P (Director, Research Laboratories, General Electric Co Ltd)

This session departed to some extent from the usual practice of the Convention in that the speaker delivered a lecture copiously illustrated by practical demonstrations and lantern slides instead of formally presenting a written paper.

This report can therefore do no more than summarize the principal points of the lecture, with an indication of those demonstrations which lend themselves to a printed description.

Mr Humphreys developed the theme that practically everything that men do calls for light, and the kind, quantity, and cost of the light which can be provided determines how well, how quickly, and at what times things can be done. He went on:

'When thinking of lamps we tend to be preoccupied with efficiency and life and to overlook the importance of their wattage rating, which may markedly affect the manner of their use. The fact that the tubular fluorescent lamp cannot be made in really large powers—the most popular rating in this country is 80 W—has resulted in fittings containing three or four lamps, each requiring its own ballast, lampholders, capacitor, radio interference suppressor, and so on, but it is not an ideal arrangement. America and the Continent, where the usual rating is 40 W, are in worse plight.

'Until recently only tungsten lamps offered reasonably good colour coupled with a high loading, but by comparison with discharge lamps their efficiency is low and their life is short. The only discharge lamps of comparable output—the high pressure mercury vapour lamps—give a very inferior colour even with a fluorescent envelope.

'Recent developments may well transform this position. This Pavilion is at this moment lighted by three 1 kW colour-corrected HPMV lamps of the latest experimental design, giving about 50,000 lumens each. (*These were specially installed for the occasion and gave a high level of illumination with an extremely close approximation to natural daylight.—Editor.*) A number of technical problems have still to be resolved before lamps of this type become commercially available. The latest advance, which is incorporated in these lamps, depends not only on the use of the latest powders but also on the addition of zinc vapour to the discharge. In this way some of the gaps in the mercury spectrum are filled in.'

One of the factors which determines building design is the need to provide daylight to the interiors. 'Daylight is not, as usually assumed, free and in infinite supply', he said. 'It is relatively scarce and very costly; and the lamp, lighting, and power industries can now provide a cheaper substitute. Good artificial light enables the architect to provide a bigger building for the same cost and to make all of it equally useful.

'The lives of hot cathode fluorescent lamps are now well in excess of the minimum rated life of 5000 hours; cold cathode lamps last for 20,000 hours or more, and the limit has not been reached. Even if lamps are burned for the whole of the 2500 hours which constitute the normal annual working hours in an office, the installation life of hot cathode lamps now approaches four years, and that of cold cathode lamps eight to ten years.'

In the home, said Mr. Humphreys, the tungsten lamp is still supreme, and the modern trend in the design of fittings has been helped by the reduction in size of general lighting service lamps, of which three bulb sizes now cover the whole range up to 200 W.

Dealing with some of the more technical aspects of fluorescent lamps, he pointed out that attempts—particularly in the USA, where the most usual lamp is only 40 W as compared with our 80 W—to produce lamps of higher output and loading necessarily resulted in a decrease in efficiency, and he showed a curve demonstrating that the loading corresponding to the highest efficiency is about 10 W per foot (30·5 cm), which is the rating of the 4-foot (1·22 m) 40 W lamp in general use in most parts of the world. In this country, in order to get more light, we sacrificed a little efficiency and chose the 5-foot (1·52 m) 80 W lamp, with a rating of 16 W per foot—a very good compromise. Until recently it was the most highly loaded low pressure fluorescent lamp in the world.

The curve showed that as the rating is further increased, the efficiency falls off more rapidly, and of the new American lamps with a loading as high as 25 W per foot, Mr Humphreys said that the higher light output

was obtained at the price of reduced efficiency, shorter life, and poorer lumen maintenance.

He next showed another interesting development: the fluorescent tube with a built-in diffusing reflector which covers about two-thirds of the circumference of the tube. The reflector consists of a thin layer of titania between the glass and the fluorescent powder.

Moving from work to leisure, Mr Humphreys referred to floodlit football and demonstrated that, in light from too many directions, the ball looked flat like a disc; directional lighting showed it as a ball. In this field the tungsten filament lamp is unchallenged, and then Mr Humphreys introduced a new tungsten lamp—which he described as the first important development in these lamps since the coiled coil—in the form of a tubular quartz lamp, rather like a pencil, with an axially mounted filament. Developed originally for heating, he said it promised to give a very useful light source which can be easily focused mechanically, causes very little obstruction to the light leaving the reflector, and—thanks to its quartz envelope—requires no protection from the weather.

He continued: 'The theatre, the cinema, and television also depend essentially on light. For the projection of colour film the carbon arc is still the mainstay and has unique advantages. Until recently it was unchallenged, but now the high pressure xenon lamp offers many of the advantages without the fumes associated with the carbon arc.

'This country has contributed more than any other to the understanding of street lighting, and the lighting of our streets is second to none, notwithstanding some spectacular foreign installations.

'At present the sodium lamp is undoubtedly the mainstay of public lighting in this country and it has been passing through a period of very active development. Indeed this lamp, now running at about 90 lumens per watt, is the most efficient artificial light source known. The detachable Dewar flask, which maintains the temperature of the lamp and thereby the vapour pressure, has been displaced in a recent design in which the discharge tube, with heat-insulating sleeves, is sealed into a single walled highly evacuated jacket, thus simplifying the design and improving the lamp; it has started a train of thought which may lead to still further simplification. Another development is the use of two 140 W inner tubes in a single jacket, giving for the first time a 280 W lamp, emitting nearly 20,000 lumens. Other lamps are also appearing which are more heavily loaded than the established 140 W lamp.

'Our railways are very dependent on light in many ways. The Underground railways of London, the most extensive in the world, are wholly dependent on light.

'Air services are dependent upon lighted aids for landing and take-off—the most critical stages of the flight—notwithstanding all the modern radio aids. Indeed, the better the radio aids, the greater the strain upon the visual aids, for the pilot is given less time in which to make use of them.

'In the aeroplane itself the passenger may more readily enjoy the benefits of fluorescent lighting, as may also the traveller by train, as the result of the recently developed transistor-inverter circuits which enable fluorescent lamps to be operated efficiently on high frequency ac derived from low-voltage dc supplies.

'Lighting is an essential part of architecture. Many of our finer public buildings, and especially our churches and cathedrals, have beauties of form, of colour and workmanship which are hidden or spoiled at night, and often only inadequately revealed in daylight, and lighting systems such as that recently installed in Gloucester Cathedral show what can be done.

'My subject is almost as wide as life itself; wherever I stop, there will be aspects untouched. I have had no time to dwell on light in surgery and medicine; light in the theatre, where in many ways it is most fully an art form; on the many special problems such as those presented by corrosive and explosive atmospheres, or on many others; but I think that this is a fitting point at which to close this brief review of the many benefits which derive from lighting and the multifarious ways in which it contributes to the common weal.'

The final session of the Convention took the form of an 'Electrical Forum', at which questions of general interest submitted by delegates were answered by a panel consisting of Sir Henry Self, KCB, KCMG, KBE, Chairman of the Electricity Council; Sir Christopher Hinton, KBE, FRS, Chairman of the Central Electricity Generating Board; Mr H. G. Nelson, MA, MICE, MIEE, MIMECHE, managing director of The English Electric Co Ltd; and Mr W. S. Lewis, CBE, JP, COMP IEE, Chairman of the Midlands Electricity Board. Mr C. R. King, President of the Convention, officiated as Question Master.

This was followed by the Annual General Meeting, at which Viscount Chandos, DSO, MC, Chairman of Associated Electrical Industries Ltd (AEI), and Sir John Pickles, BSC, Chairman of the South of Scotland Electricity Board, were unanimously elected President and Vice-President respectively for the ensuing year.

The next Convention will be held at Bournemouth from May 30 to June 2, 1960.

Finally, the vote of thanks to the President and to Mrs C. R. King was proposed by Mr S. F. Steward, Director of the BEAMA, who emphasized the heavy burden of work which falls on the President and his lady during Convention week. It had been, said Mr Steward, a most successful Convention, but above all a friendly Convention, thanks to the warm-hearted personalities of Mr and Mrs King and the great genius for friendship which they both possessed in large measure.

That Mr Steward had expressed the feelings of all the delegates was shown by their enthusiastic acclamation of the President at the end of his year of office and the end of the eleventh British Electrical Power Convention.

Book Reviews

Rules governing the Short-Circuit Testing and Certification of Low and Medium Voltage Electric Fuses for use on Alternating Current Circuits. *ASTA No 20, 1959.* 10 × 7½ *in* (254 × 191 *mm*). *Pp* 16. (*London: The Association of Short-Circuit Testing Authorities.*) Price 10s.

These rules have recently been published by ASTA (superseding ASTA No 6, 1950) in order to amplify and clarify certain clauses in BS 88 and other standards which have given rise to misunderstanding. The rules cover procedure for identification of fuses, data to be recorded, deviations from British Standards, assessment of performance, information to be included in the records of proving tests for breaking capacity ratings and also range of applicability of certificates of short-circuit ratings for cartridge fuses and fuse links. Problems that may arise and that are not covered by these rules will be decided by mutual agreement by the Testing Authorities and these decisions will then be included in revisions of the rules. These rules will fill a long-felt need in the industry and will contribute to a higher standard of product with additional safety to the user.

Automation Today and Tomorrow. *By L. Landon Goodman.* 8¼ × 5½ *in* (222 × 140 *mm*). *Pp vi* + 275. *Index.* (*London: Iota Services Ltd*, 1959.) Price 40s net.

One of the difficulties in dealing with the literature of automation is to know what the author means by the word 'automation'. The author of the present work defines it as 'the technology of automatic working in which the handling methods, the processes, and the design of the processed material are integrated to utilise as fully as is economically justifiable the mechanisation of thought and effort, in order to achieve an automatic and in some cases a self-regulating chain of processes'.

This gives plenty of scope, and in the first half of the book the author discusses the many factors which enter into the successful use of automation in industry.

The sub-title of the work, 'A technical survey of current progress', would lead one to expect a highly technical and detailed account of automatic processing and handling. The author, however, treats it on a much wider basis, starting with considerations of the importance of mechanization, planning for automation, the situation in regard to manpower, the need for research, and sales requirements. A brief chapter treats automation in packaging and another deals with warehousing. Building design for automation occupies another chapter. Computer control of processes is dealt with in four pages, processing methods in two. Automation assembly, industrial finishing, inspection, and testing all have been given their place in the book, while, quite rightly, the author has dealt with automation in specific industries at some length.

As we have indicated, the first part of the book covers an extremely wide range of aspects of automation, and considerations of space limit the author to general descriptions as to what is or can be done, without going into detail as to how it is done and without the use of any illustrations whatsoever.

Fortunately, lack of the detail that a production engineer might hope to find is amply made up for in the second part of the book which comprises a bibliography of the automatic factory. Here is indicated briefly but concisely the content of some 850 articles on various aspects of automation which have appeared in the technical press in recent years. From this the reader can pick those on subjects in which he is particularly interested and obtain the relevant publication.

Summing up, the first part of the work gives the reader a general review of recent applications of automation in many industries in Great Britain, makes some observations on the future, and provides a very useful permanent work of reference of articles on modern manufacturing techniques.

Economic Operation of Power Systems. By *L. K. Kirchmayer.* 9¼ × 6 *in* (235 × 152 *mm*). *Pp viii* + 260. *Illustrated. Index.* (*New York: John Wiley; London: Chapman & Hall*, 1958.) Price 96s net.

Anyone who has had the need to calculate 'longhand' the losses in electrical systems other than of the simplest kind must sometimes have been appalled at the magnitude of the arithmetical task to achieve accuracy. Ideally, to be taken into account there are the resistances and the impedances of overhead lines and cables, the effect of spurs and interconnectors, load factors that vary from part to part of the system, temperature variations, the resistance and impedance characteristics of generators, motors, transformers, and feeder regulators, diversity factors, maximum demands that daily, weekly, and monthly change with the weather, voltage variations, and load transfers. Faced with such a discouraging programme it is not to be wondered at if the system engineer sometimes throws up his hands in despair and says 'Oh, let us say the total losses are x per cent'.

If, however, the system engineer has a knowledge of modern matrix methods of analysis plus the use of a network analyzer or a digital computer, then his difficulties can almost vanish overnight. Reasonably quickly he can obtain an accurate answer to his losses problem and he can tackle systems of such complexity that previously would have been considered quite intractable. Dr Kirchmayer's book shows how this is done. Broadly speaking, matrix methods are first used to derive and calculate transmission loss formulae which provide the means of dealing with systems in a simple manner as well as leading to orderly computational procedures which can readily be handled by digital computers. The system can be simulated on a network analyser and for any given operating conditions the losses in individual parts can fairly easily be derived from analyzer meter readings of currents, voltages, power factors, kW, and kVAr. The loss values are then included in the appropriate matrix equations which latter are solved on a digital computer to determine the overall effect on the system. Alternatively, suitable tests can be made on the actual system to derive the data required for the various matrix equations.

This then is the theme of the present book, which shows the development of transmission loss formulae, the practical calculation of loss formulae coefficients, the coordination of incremental production costs and incremental transmission losses for optimum economy, transmission losses as a function of voltage phase angle, and various other features closely connected with the problem of system economic operation.

The loss formulae as they stand to-day have progressively been developed by a number of workers in this field from the original work of E. E. George published in 1943, aided in a considerable degree by Gabriel Kron's fundamental work on this particular subject. The importance of the new technique can be assessed from Dr Kirchmayer's citations that 'improvements in fuel economy of approximately 50,000 dollars per year per 1000 MW of installed capacity have been achieved in a number of systems by including the effects of transmission losses by means of the transmission loss formulas given', and that in connexion with the cost of losses in interconnexion transactions '. . . the value of the losses incurred by one large operating company in supplying and wheeling power to certain atomic energy loads was of the order of magnitude of one million dollars per year'.

This book is one of great importance to power supply engineers having the responsibility of the economic operation of large interconnected systems. Dr Kirchmayer has another book in preparation, *Economic Control of Interconnected Systems*, and we imagine that the two together will be found to constitute a major landmark in the history of the technical development of commercial electricity power supply systems. The book contains many bibliographical references for further study of the subject and also numerous problems set to enable the reader to gain some experience in applying the methods described.

We believe there will be a pressing demand for the book when once its contents become known.

S. AUSTEN STIGANT

Telecommunications. *By A. T. Starr. 2nd edition.* 8¼ × 5½ *in* (222 × 146 *mm*). *Pp ix* + 470. *Illustrated. Index.* (*London: Sir Isaac Pitman*, 1958.) Price 37s 6d net.

It is notable that a second edition of a book on a specialized subject should be required so soon. This contains only slight amendments to the text and further examples for the reader to test the knowledge he has acquired from his studies.

P. F. SOPER

Laplace Transforms for Electrical Engineers. *By B. J. Starkey.* $8\frac{3}{4} \times 5\frac{3}{4}$ *in* (222 × 146 *mm*). *Pp* 279. *Illustrated. Index.* (*London: Iliffe & Sons Ltd*, 1954. *2nd Impression*, 1958.) Price 30s net.

This book is another example of the engineer breaking into the field of the mathematician with considerable advantage to the former class. The author is quite right when he says 'mathematicians use language which is rather difficult for the uninitiated' and that is not necessarily the fault of either party. In the present case the situation is largely remedied as the subject is explained in the vocabulary of the electrical engineer and in terms with which he is familiar.

The initial approach is by way of vector analysis, Fourier transformation, and generalized impedances, passing on to the Laplace transforms and applications to a variety of simple electrical circuits. Then follow chapters on functions of a complex variable, integration in the complex plane, and analysis of contour integration. The last four chapters deal explicitly with the Laplace transformation, covering its theory, applications and theorems, use of the inverse transformation, and generalization of the theory. Three appendices are provided on analytic functions, higher mathematical functions, and a table of inverse Laplace transforms.

The mathematics standard is not beyond the capabilities of the electrical engineer familiar with the differential and integral calculus, the operational calculus, analytic functions, and electrical circuit theory.

Although the book has a certain light current bias by reason of the author's professional interest, its value is in no way restricted thereby. It is an excellent book for all classes of electrical engineers whose work calls for the application of transform theories and we recommend it to both advanced students and professional engineers.

The book is well produced and clearly printed, and the low price places it easily within the reach of most of those likely to be interested in it.

S. AUSTEN STIGANT

Problems in Electronics with Answers. *By F. A. Benson.* $8\frac{3}{4} \times 5\frac{1}{2}$ *in* (222 × 140 *mm*). *Pp* *x* + 219. *Illustrated. Index.* (*London: E. & F. N. Spon*, 1958.) Price 36s net.

This new book of 282 problems on electronics is divided into two parts: Part Two giving worked solutions to the problems classified in Part One.

The problems, contained in 23 chapters with each chapter dealing with a specialized topic, are intended to assist undergraduate students in the application of theory in the subject of electronics. In this way the student is assisted to overcome many of the difficulties encountered when first applying theoretical principles to a practical problem in a new subject. In this connexion the title of the book is somewhat misleading, since 110 problems deal with non-electronic topics, being either general electrical technology or else telecommunications. Examples of this are the chapters on Wave-form Analysis and Waveguides.

There is undoubtedly much confusion on what is intended to be treated in a syllabus on electronics. At the present time this subject is cluttered up with material more appropriate to other studies.

As far as can be judged, the rest of the problems are representative of the subject, appropriate for student use, and the solutions do not contain obvious errors of statement. Whether it is desirable for worked solutions to be produced in book form is a debatable question. Many eminent educationalists consider that this is a vicious form of spoon-feeding. It may well prevent students thinking for themselves and thus developing self-reliance.

P. F. SOPER

Synthesis of Linear Communication Networks. *Vols 1 and 2. 2nd edition. By Wilhelm Cauer.* $9\frac{1}{4} \times 6$ *in* (235 × 152 *mm*). *Pp* 865. *Illustrated. Index.* (*London: McGraw-Hill*, 1958.) Price 151s net.

The publication of this book, as a translation of the 1941 German original *Theorie der linearen Wechselstromschaltungen*, is an event of considerable importance to all those having a major concern with the theory of electrical networks. Cauer was that ideal combination of electrical engineer, physicist, and mathematician, and to all these fields of endeavour he made substantial contributions. His prime life interest, however, was in network theory, to the study of which he applied an unbounded energy and a ranging outlook derived from the threefold activity that had provided his scientific background. Cauer died at an early age and it is a lasting testimony to the originality, the thoroughness, and the high standard of his work that to-day there is hardly any important book or paper on network theory that does not contain a reference to his work.

The present book is written as a two-volume work and in all it contains eleven chapters and seven appendices. The first volume provides the basic theory of network analysis and synthesis, a discussion of the image-parameter method, a collection of formulae, and practical means of filter design with the aid of tables and design charts. The second volume discusses the insertion-parameter design method, band-separation networks, network equivalence, practical design aids, mathematical foundations of circuit theory, a commentary on latest advances in network theory, and an extensive bibliography. In addition to the subjects specifically mentioned there are chapters on two-terminal-pair networks, reactance theorems, and reactance networks.

The branches of mathematics employed in the book are those relating to linear algebra including an extensive use of matrix theory, the theory of complex variables, and the combinatory topology of line complexes. Throughout the mathematical work emphasis has been laid upon accuracy and rigour but there is no unnecessary (to this book) burden of mathematical proofs.

Although the book is addressed formally to communication engineers its value to those in the power field is just as great, as the literature published since 1941 unmistakably shows. Indeed the German edition has achieved world-wide renown and the present English translation will undoubtedly be the means of deepening and extending the appreciation of Cauer's work in English-speaking countries.

By the highest standards the production of the book is first rate in all respects, and network engineers are indebted to the publishers (as well as to the translators) for having made an English edition available.

S. A. S.

Mathematics Applied to Electrical Engineering. *Vol 9. 2nd edition, revised and enlarged. By A. G. Warren.* $8\frac{3}{4} \times 5\frac{1}{4}$ *in* (222 × 146 *mm*). *Pp* *xvi* + 464. *Illustrated. Index.* (*London: Chapman & Hall*, 1958). Price 70s net.

The popularity of this book is evident from the fact that the first edition of 1939 has gone through six impressions. Clearly, after nearly twenty years, a revision was due and that is what we now have.

Apart from the usual corrections, deletions, and relatively minor additions that are customarily made in a new edition the principal changes consist of the following:

The two chapters on operational calculus and on Fourier analysis have been completely rewritten and a chapter on functions of a complex variable has been added. Harmonic analysis has been removed from the chapter on Fourier series to make room for a section on the Fourier integral. In appropriate places new sections are included on analogues, analogue computers, eddy current methods of non-destructive testing, and on carrier wave modulation. The section on electromagnetism now contains a brief review of the mks rationalized system of electrical units, but otherwise the book employs the cgs system.

The new edition is a considerable improvement on the previous one but the price seems unduly high unless, of course, all the original type had been broken up.

Physics and Heat Technology of Reactors. *Translated from Russian.* 11 × $8\frac{1}{2}$ *in* (279 × 216 *mm*). (*London: Chapman & Hall*, 1958.) Price 168s net.

This volume consists of nineteen original papers by various Russian authors, the translations having been undertaken by Consultants Bureau, Inc, of New York. The papers fall into two groups, the first of which relates to reactor physics and the second to engineering aspects connected with heat problems in reactors.

In the first group some of the papers deal with reactor physics calculations while others describe experiments devoted to physics problems and reactors safety and also to problems associated with these subjects. In the second group the papers cover heat problems arising in power reactor engineering with special reference to those of heat removal in which one is concerned with obtaining the highest efficiency of heat removal and the highest degree of utilization of the heat generated in the reactor core. The important feature of radioactive loading of the reactor heat-removal systems also receives attention.

The papers are largely mathematical and are appropriately illustrated. References are given to the cited literature. The volume will undoubtedly interest all those working on nuclear reactors but the price is exorbitant. Its dimensions make it most unhandy.

S. A. S.

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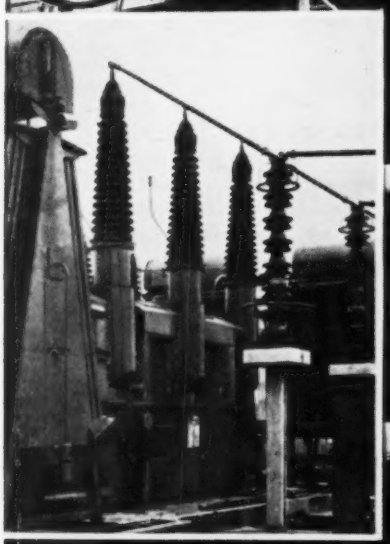

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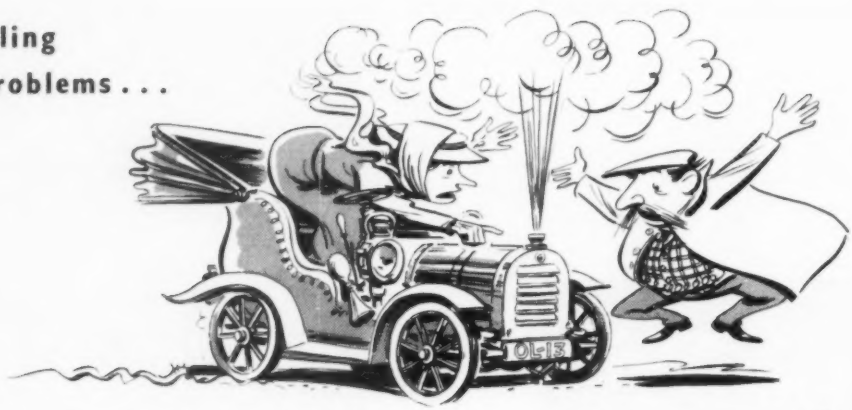

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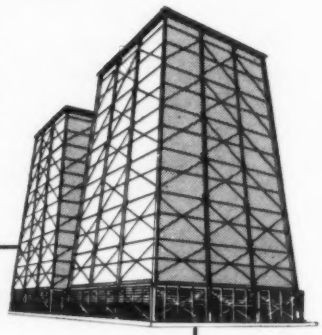

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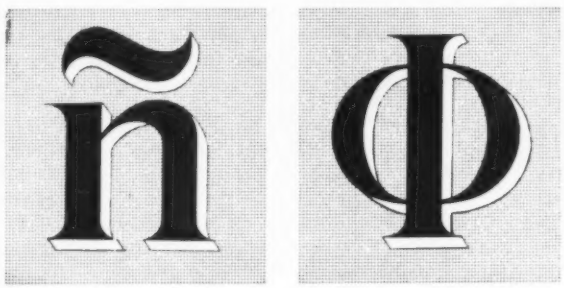

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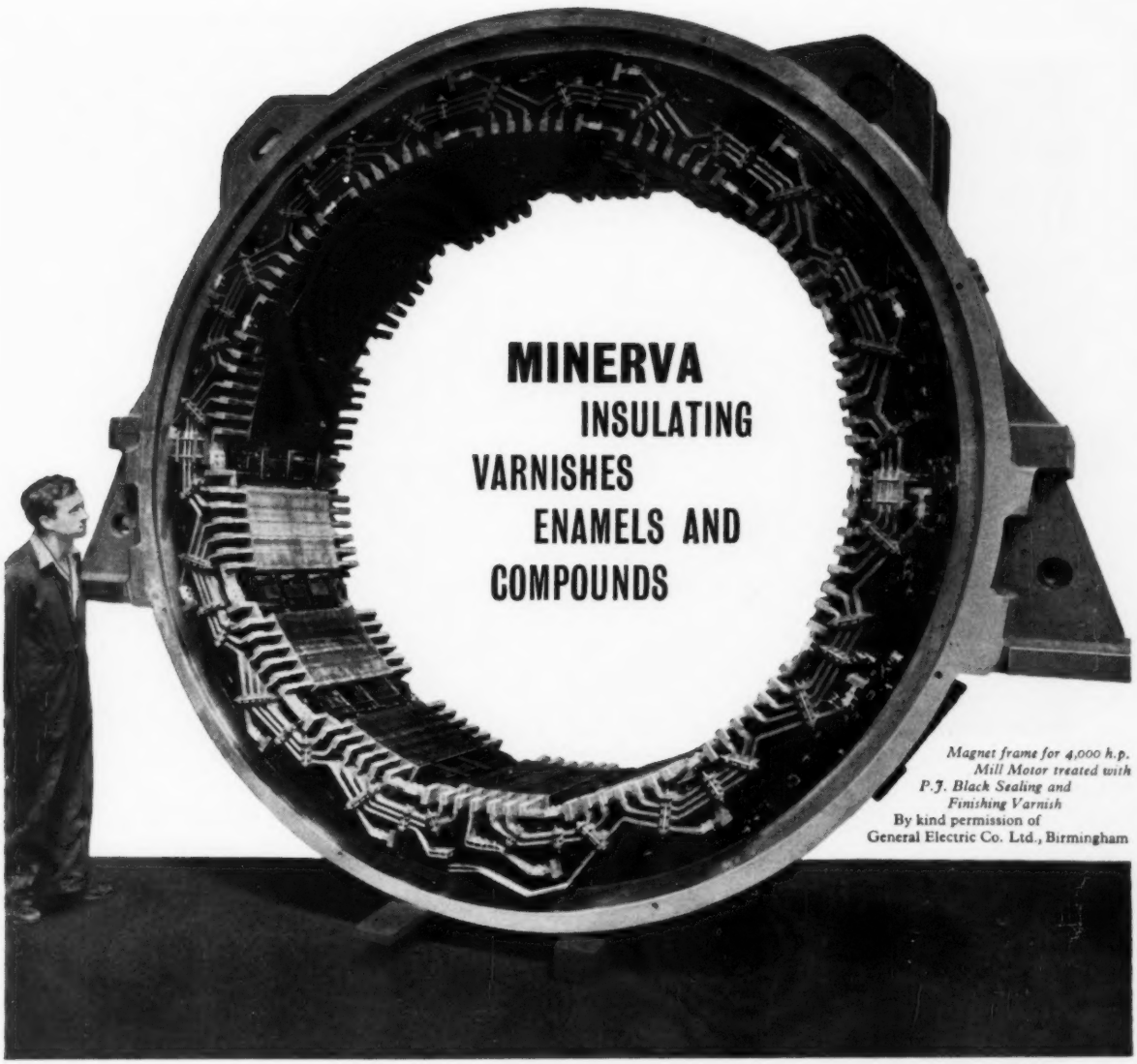

Magnet frame for 4,000 h.p. Mill Motor treated with P.J. Black Sealing and Finishing Varnish
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Additions are continually made to our range of specialised insulating varnishes and electrical machinery finishes. Recent research has largely been concerned with exploiting the latest synthetic resins, and many new formulations with characteristics of considerable interest to the electrical industry have been evolved in our laboratories. Requests for further information, or specific enquiries regarding insulating problems, should be addressed to our Insulating Varnish Department.

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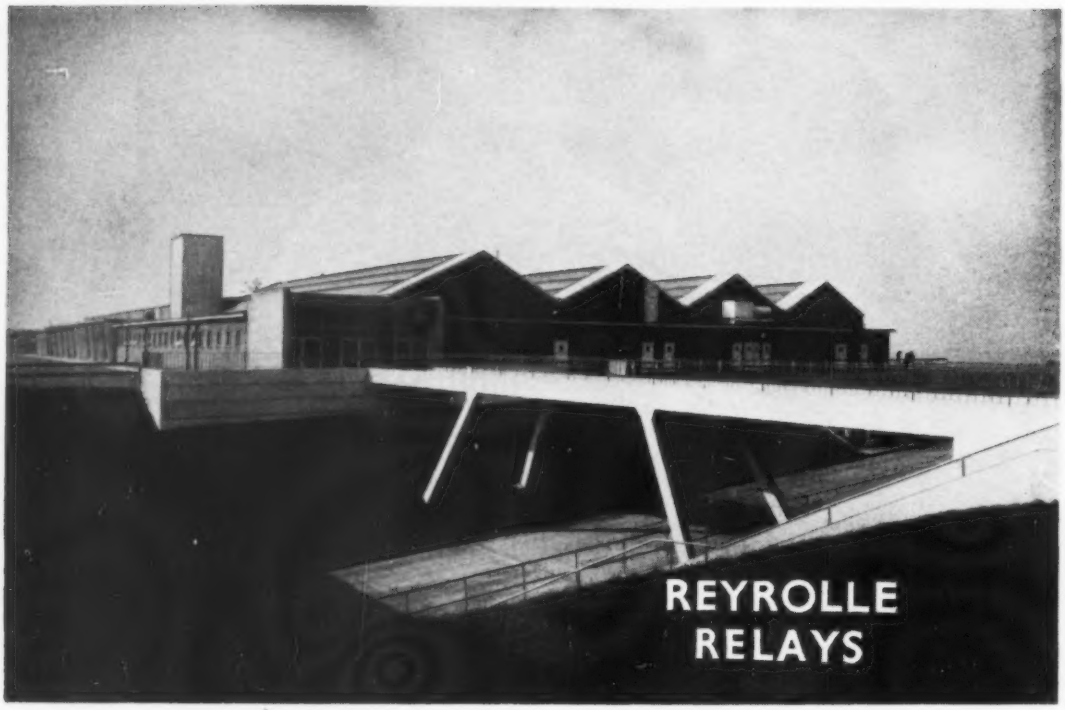

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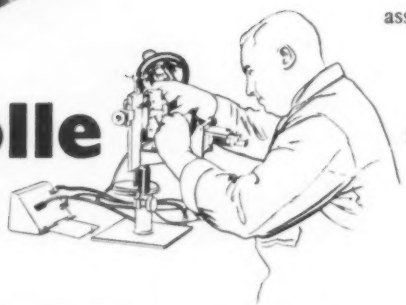

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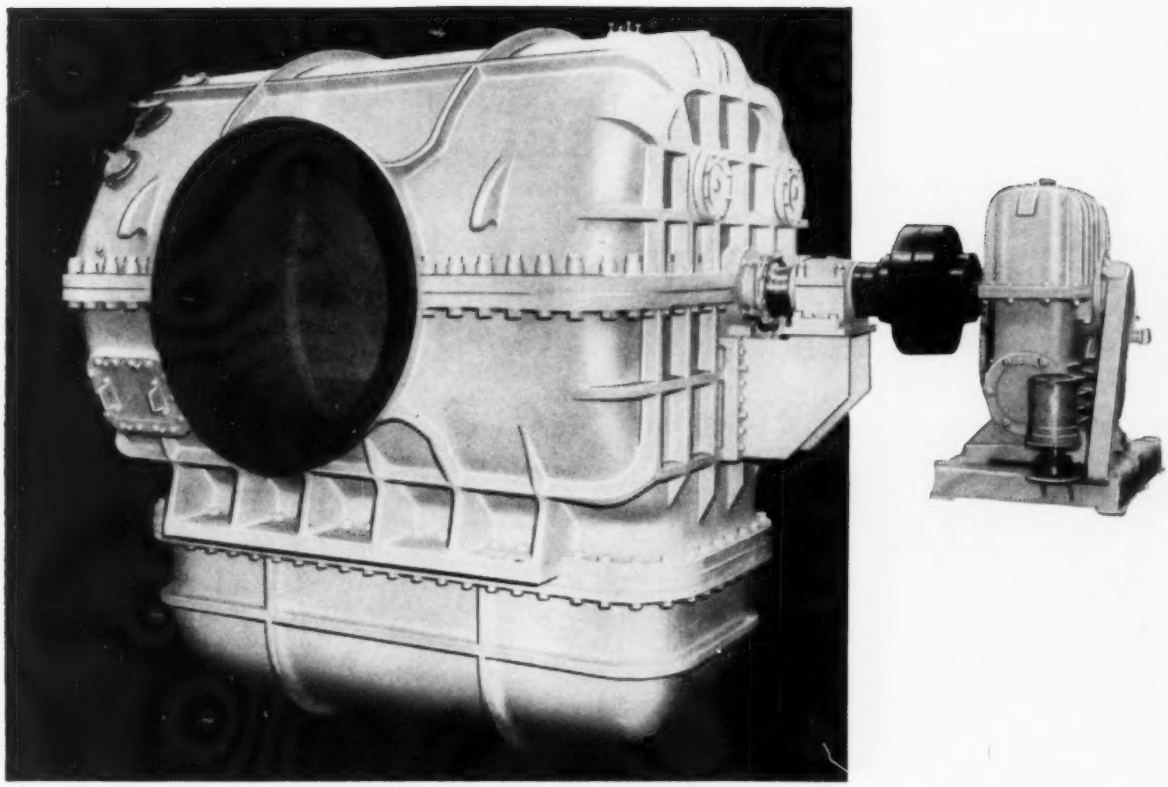

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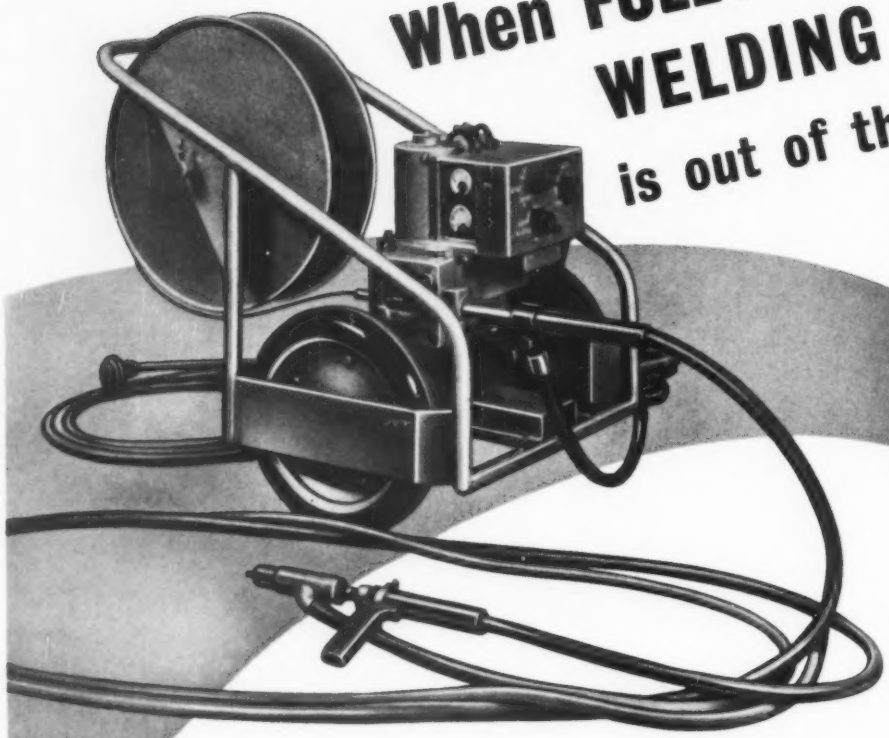

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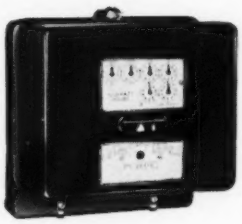

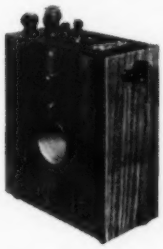

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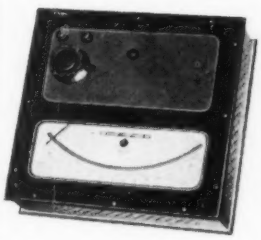

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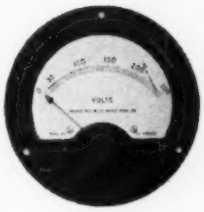

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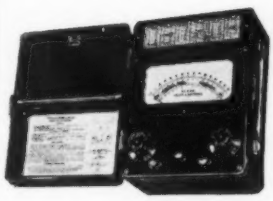

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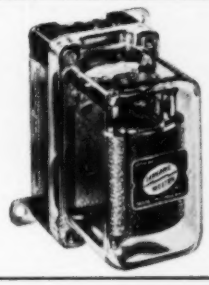

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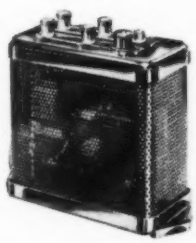

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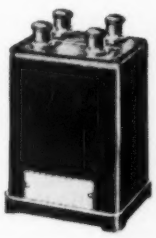

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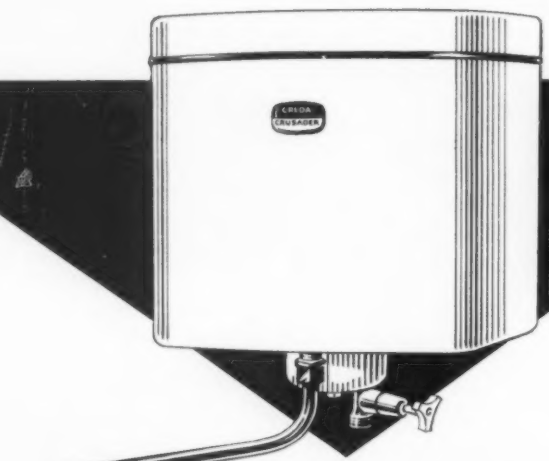

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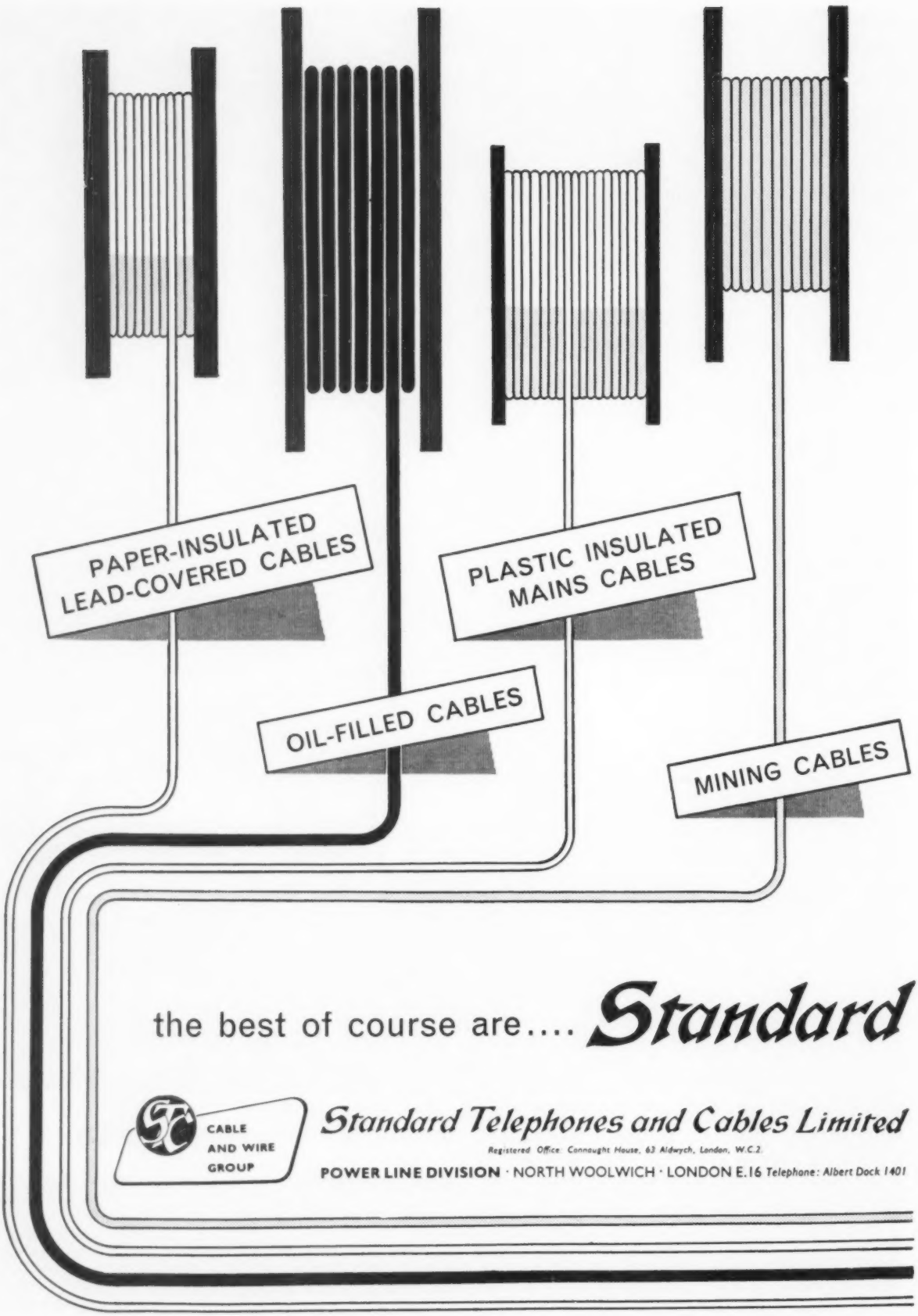

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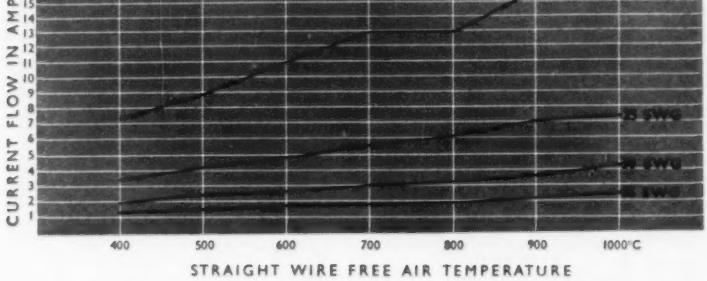
Fundamental considerations in the design of electrical heating equipment

ELEMENT TEMPERATURE—A VITAL DESIGN CONSIDERATION In designing electric heating equipment, element temperature is naturally a primary consideration for upon it depends the efficiency and reliability of the equipment. An element's life will be shortened if it is allowed to operate above the safe working limit of the material while operation below the maximum will result in a considerable extension of element life.

FACTORS GOVERNING ELEMENT TEMPERATURE Element temperature depends on two factors (1) the surface area electrical loading (usually expressed as watts per sq. in. of resistor surface area) and (2) local heat dissipating conditions. While the first can be determined accurately for any piece of equipment, the second is subject to many influences such as type of mounting, dimensions of spiral, circulation of air around the element. It cannot easily be determined exactly. The rate at which heat can be dissipated or removed from the element governs the surface area electrical loading that can be allowed. Thus certain types of water heaters and space heaters using a forced draught may be loaded to a high watts density, while an enclosed oven element may have a low watts density.

TESTING ELEMENT MATERIALS As a basis for determining desirable element temperatures, and hence suitable electrical loading, a wire of the material to be tested is held horizontally in free air and used as a datum during the test. The result of this test is known as the 'straight wire free air temperature'. Equivalent temperatures have been worked out to enable data based on this temperature to be related to many types of element.



Graph showing Straight Wire Free Air Temperature/Current Flow for Brightray C

The choice of materials for electrical heating elements is a job for the expert. Our Technical Service engineers are always ready to give advice on the selection and application of Wiggin electrical resistance materials.

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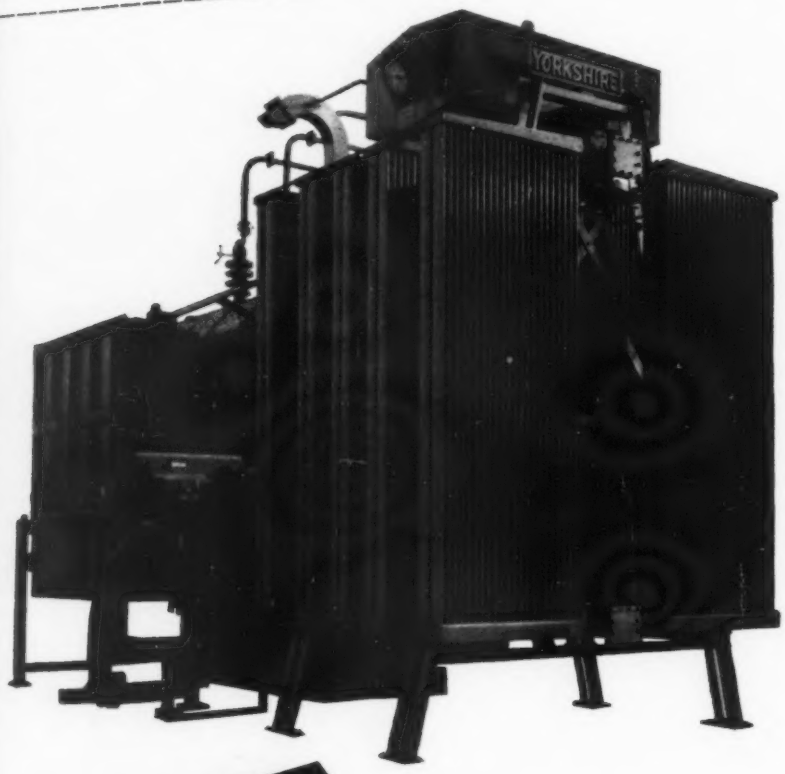

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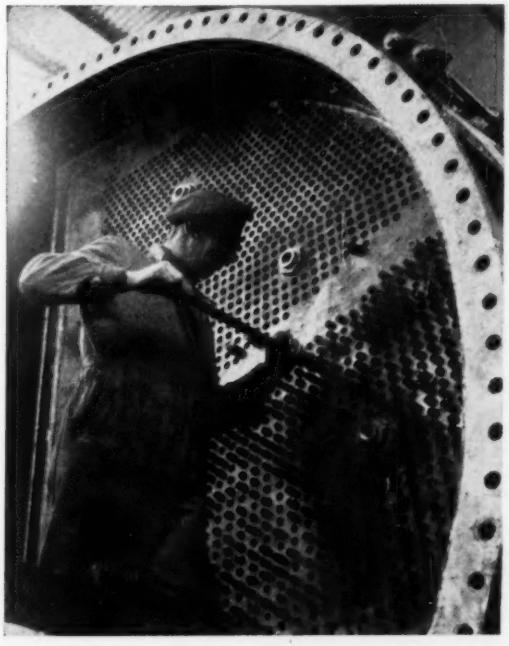

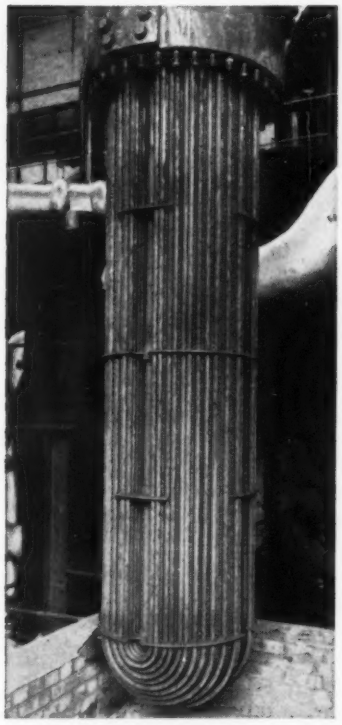

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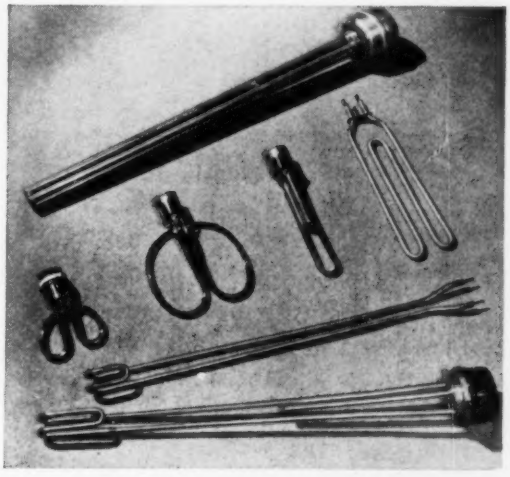

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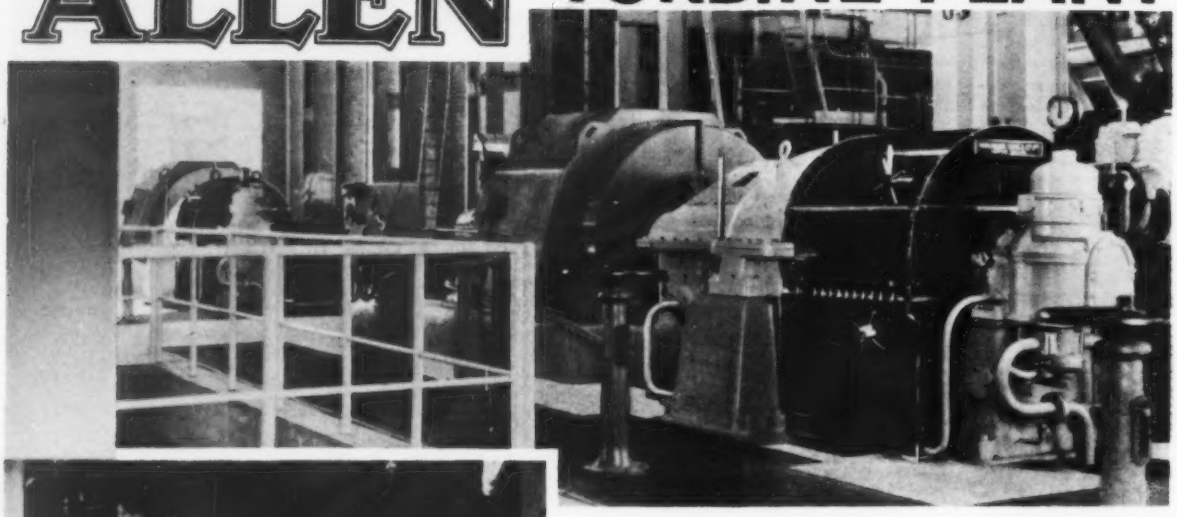

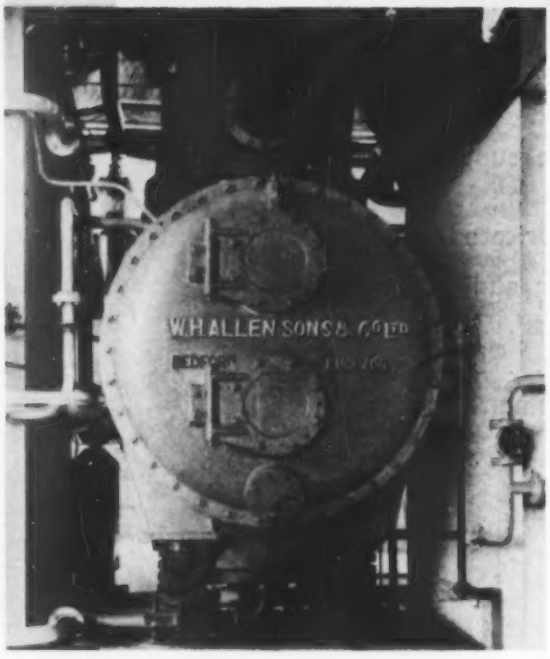

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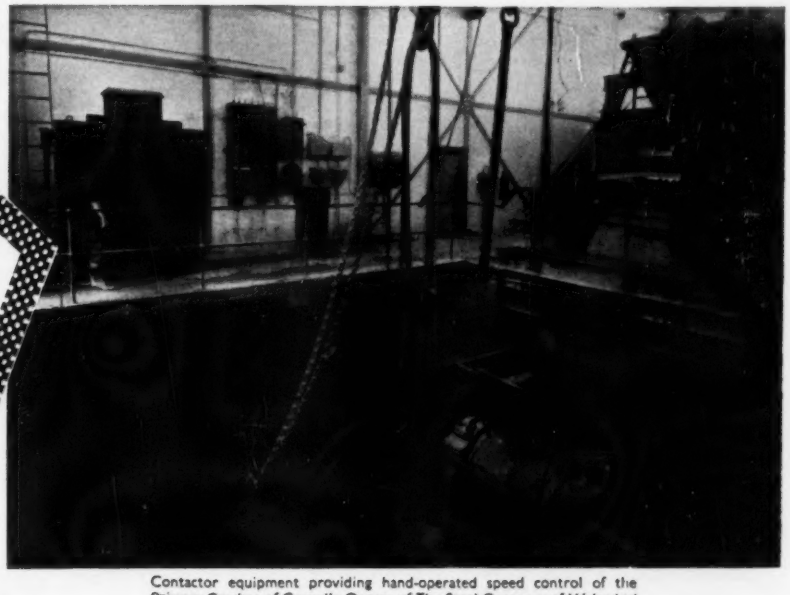
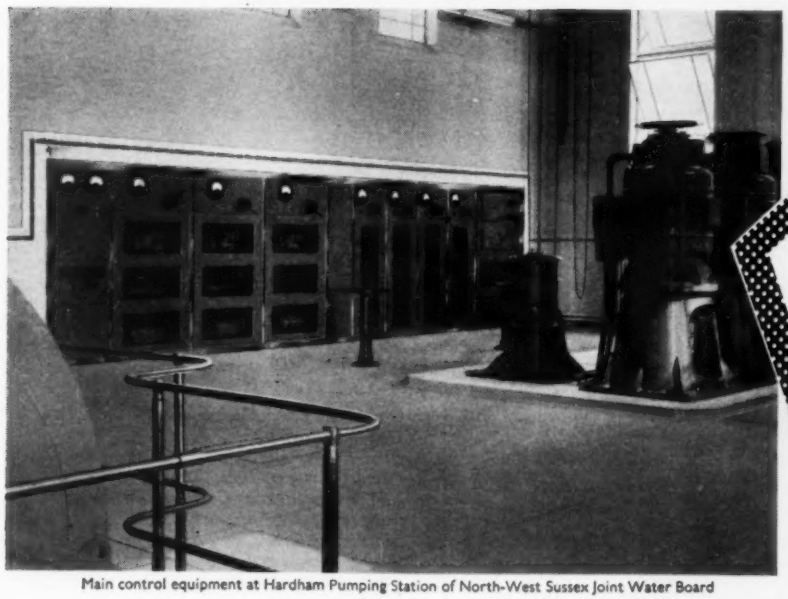


Contactor equipment providing hand-operated speed control of the Primary Crusher of Cornelly Quarry of The Steel Company of Wales Ltd



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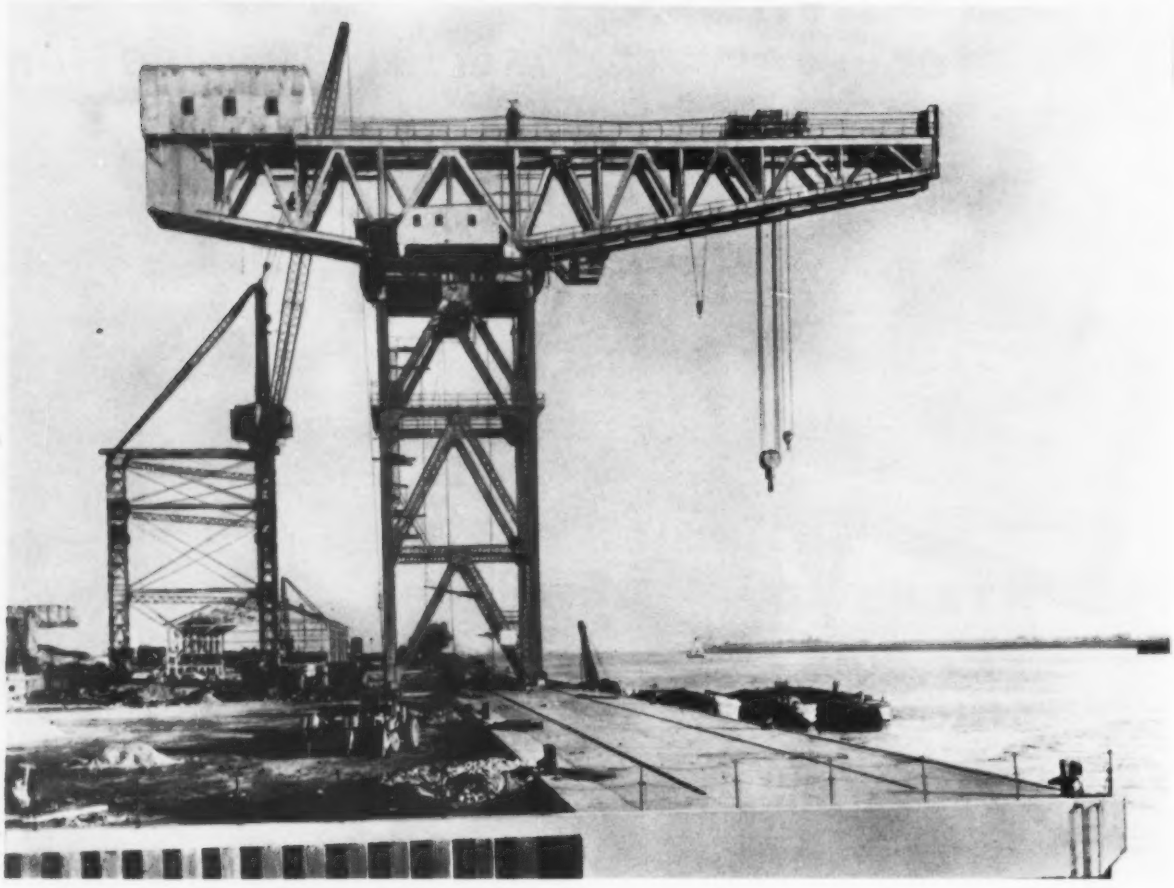

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Nature has equipped her creatures with physical attributes especially adapted to their surroundings and mode of life. In the production of HBC cartridge fuse links we emulate Nature, providing them with 'necks' or tags, best suited to their use.

Loss of production is a serious matter. If this is due to the interruption of electrical supply, the first warning is given by the all-important cartridge fuse link, whose primary function is the protection of vital and possibly costly electrical equipment.

If you produce electrical equipment incorporating cartridge fuse links, fit those of A.E.I. manufacture, they will render good service to your customers.

Similarly, when fuse link replacement becomes necessary in your own factory fuse switchgear you will be well advised to fit A.E.I. cartridge fuse links—they will never let you down.

Manufactured to one standard only—the highest, they comply in every respect with B.S. 88 1952 including dimensions to Appendix 'J', so that they will fit most of the conventional designs of fuse switches, distribution boards, control gear, etc.

Quick delivery can be made from stock at competitive prices.

Type 'Q' high breaking capacity cartridge fuse links are manufactured under controlled conditions to ensure consistent performance and interchangeability. They are available with centre or offset tags.

AEI

TABLE OF ASTA CERTIFICATE NUMBERS

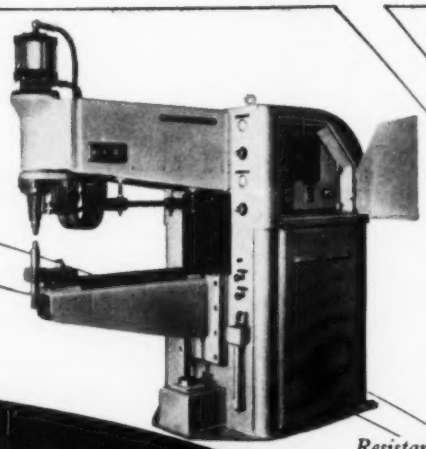
Current Rating A	*ASTA Certificate Nos.*	
	440 Volts.	*550 Volts.*
10	3194	3602
30	3198	3603
60	3202	3605
100	3158	3606
200	3160	3932
300	3162	3931
400	3461	3775
500	3463	3776

Manufactured at the Higher Openshaw Works of

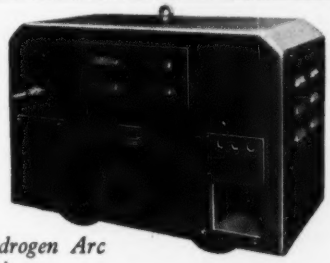
Associated Electrical Industries Limited

SWITCHGEAR DIVISION

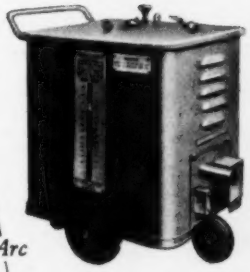
Higher Openshaw, Manchester · Trafford Park, Manchester · Willesden, London



Resistance



Atomic Hydrogen Arc



A.C. Arc

What is your need?

Choose from
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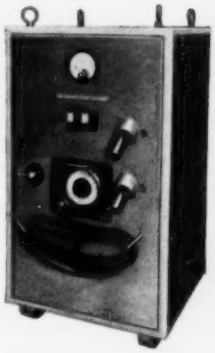
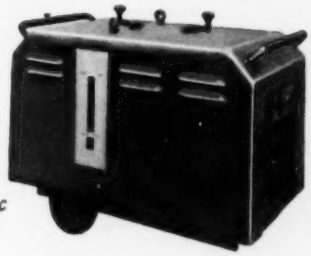
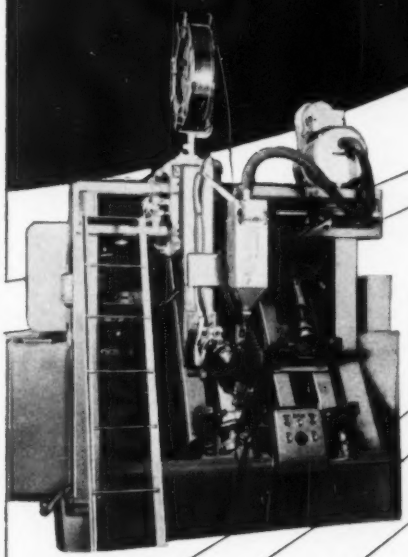
METROVICK
welding equipment



D.C. Rectifier Arc



Inert Gas Arc



Submerged Arc

Behind the range of METROVICK electric welding equipment is the research and experience of a vast engineering organisation making extensive use of this equipment in its own factories.

You have the benefit of all this when you buy welding equipment from A.E.I.

AEI

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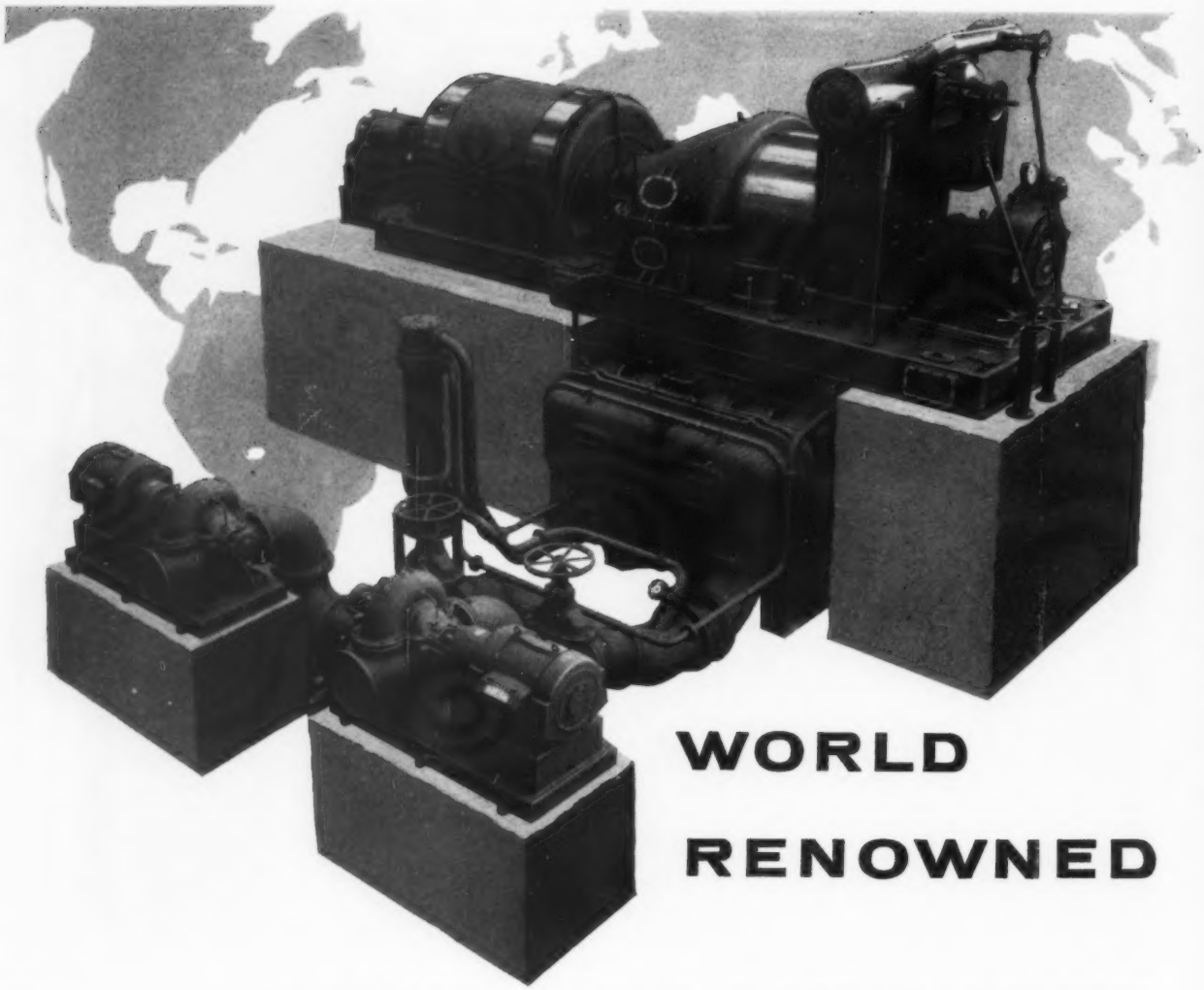
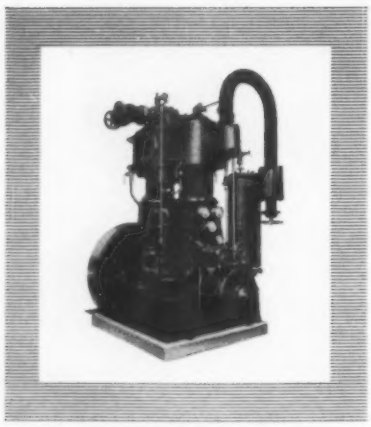


WORLD RENOWNED

STEAM TURBINES & STEAM ENGINES



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STEAM TURBINES up to 15,000 kW
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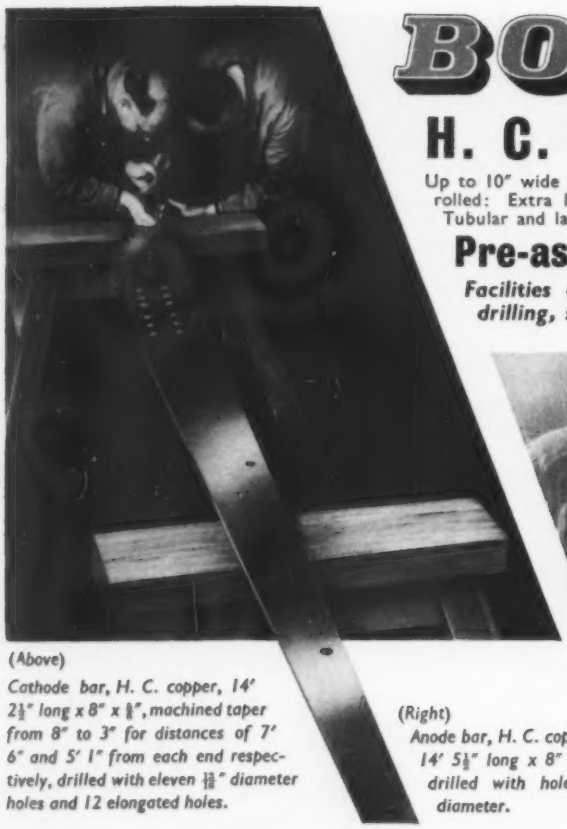

(Above)
Cathode bar, H. C. copper, 14' 2½" long x 8" x ⅜", machined taper from 8" to 3" for distances of 7' 6" and 5' 1" from each end respectively, drilled with eleven 13/16" diameter holes and 12 elongated holes.

(Right)
Anode bar, H. C. copper, 14' 5½" long x 8" x ⅜" drilled with holes 11/16" diameter.

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Telephone: Widnes 2022

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P.17

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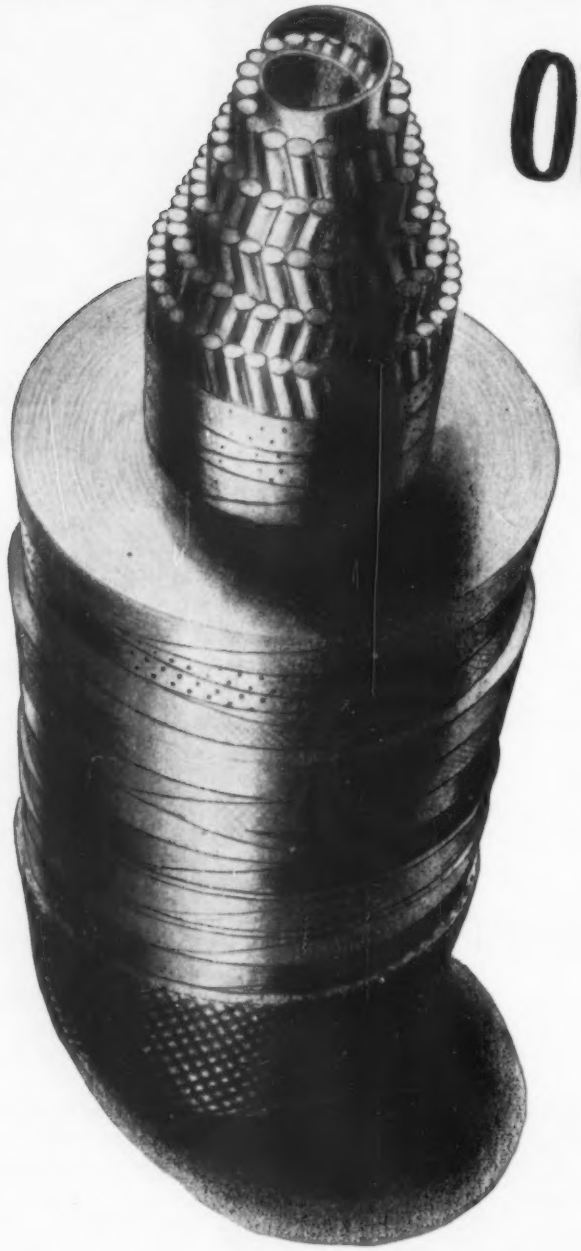

BICC transmission equipment plays a large part in the development programme being carried out by the British Columbia Electric Company. Twenty-eight miles of BICC 230 kV single-core oil-filled cable have been supplied for a transmission network from Kidd Substation on the north arm of the Fraser River to distribution points in Greater Vancouver. Another major dollar earning contract for BICC and Britain.

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North Point Power Station

HONG KONG

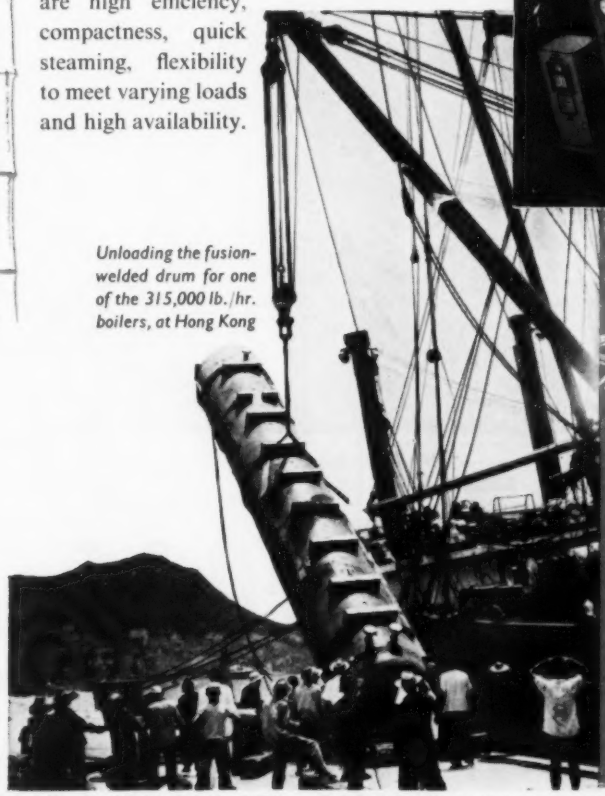
The North Point 'A' power station of the Hong Kong Electric Company Ltd. is equipped with 22 boilers all supplied by the BABCOCK organization, the last three of these being oil-fired Integral Furnace units of 150,000 and 200,000 lb./hr. capacity, with steam conditions of 425 lb./sq. in. and 775°F.

The new and adjacent North Point 'B' station will have a capacity of 150 MW, and the first three boilers installed are again BABCOCK oil-fired Type FH units, of larger capacity, i.e. 315,000 lb./hr. at 625 lb./sq. in., 865°F.

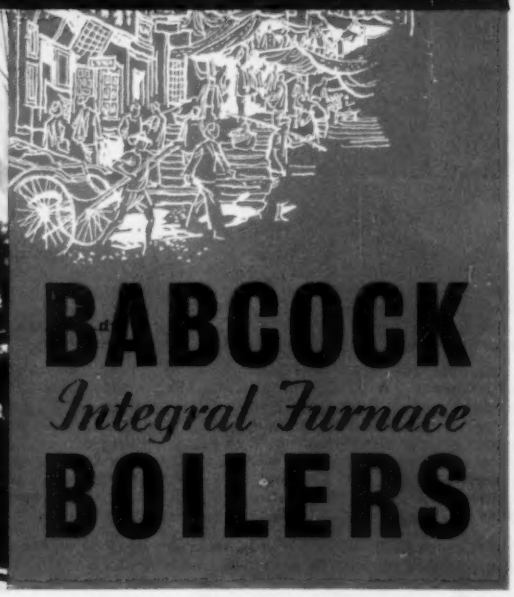
The selection of BABCOCK Integral Furnace boilers for the new station, following experience with similar units at North Point 'A', endorses the good performance of this type, the outstanding characteristics of which are high efficiency, compactness, quick steaming, flexibility to meet varying loads and high availability.

Aerial view of the stations, with North Point 'B' in the foreground

One of the 315,000 lb./hr. boilers from the control and turbine-floor level



Unloading the fusion-welded drum for one of the 315,000 lb./hr. boilers, at Hong Kong



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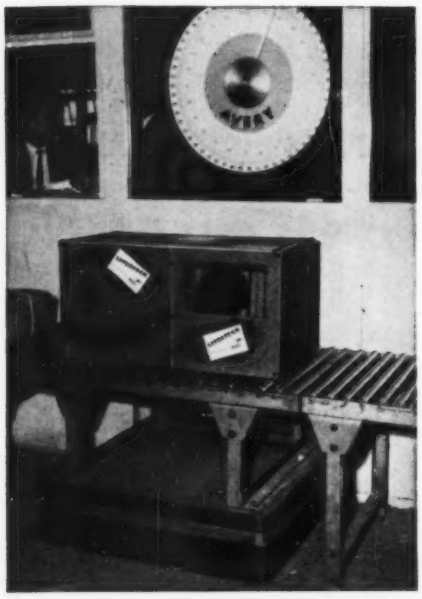

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BOAC gives your cargo jet-age treatment all the way. And here are samples of the services which speed your goods around the world. . . .

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India	16
Pakistan	15
Australia	11
Singapore/Malaya	13
Hong Kong ..	9
Caribbean ..	5
Japan	4
Middle East ..	30

All over the world

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takes good care of your cargo

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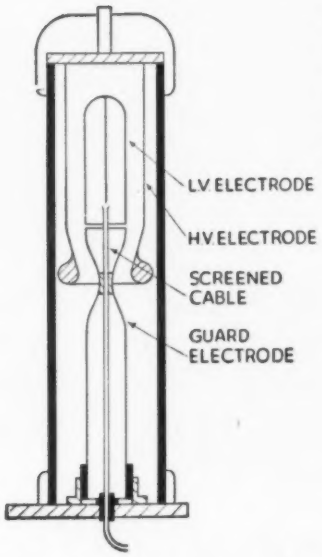

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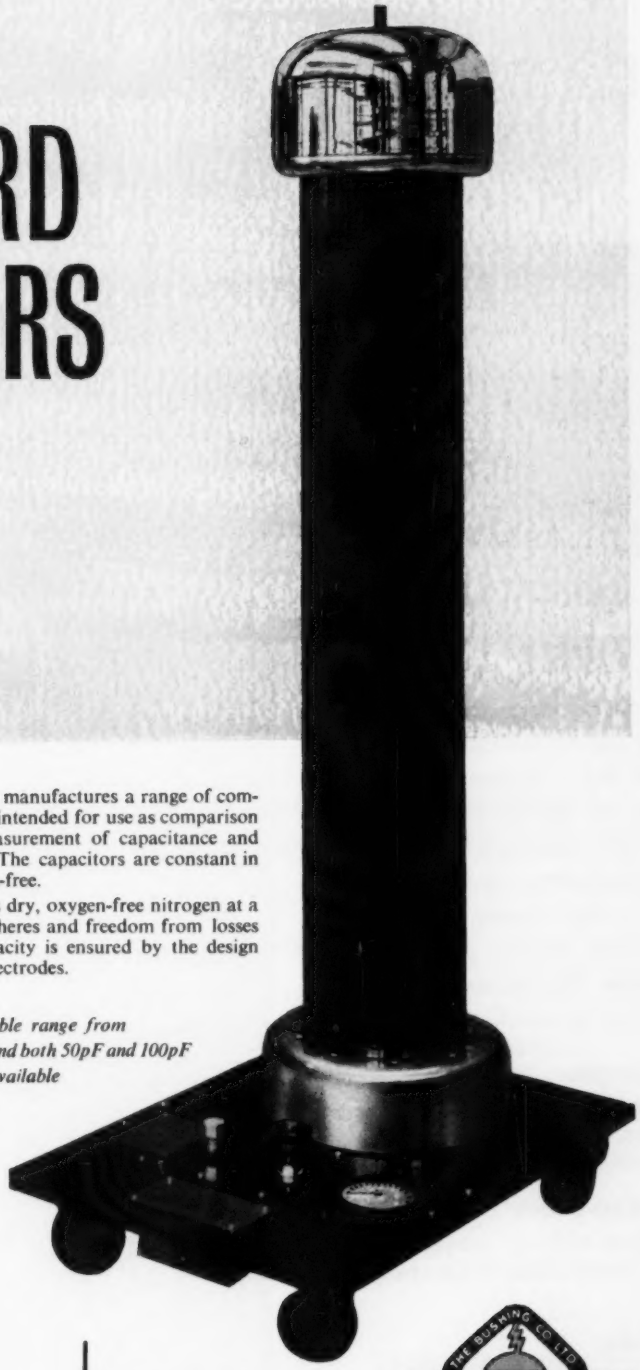

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so adaptable
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so safe
Short-circuit protection up to 35 MVA.

so easily serviced
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so cheap
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DRY TYPE AIR COOLED CLASS-C TRANSFORMERS

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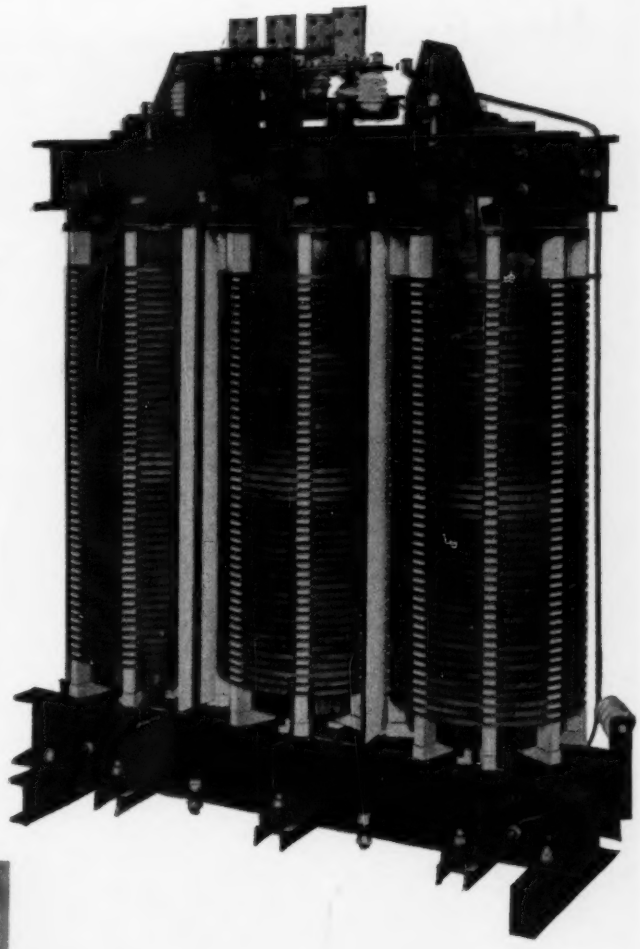

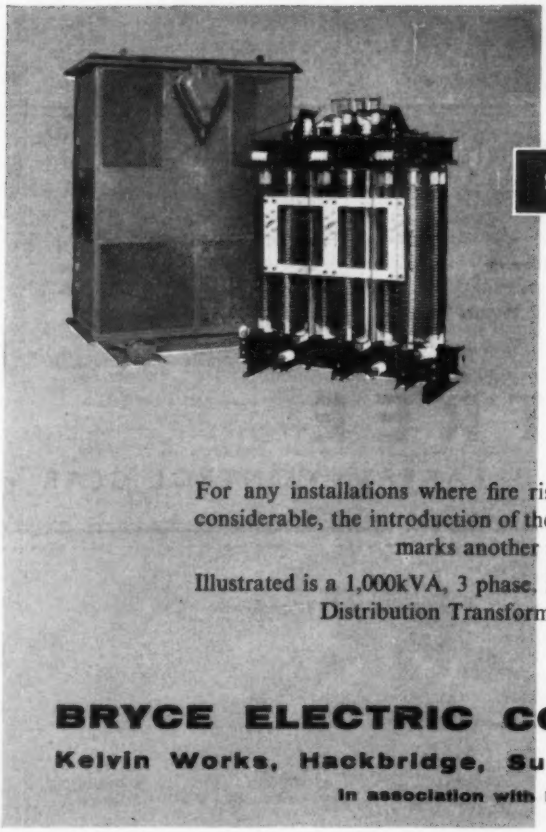

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- Reduced Weight
- Higher Overload Capacity
- Can be installed in damp locations

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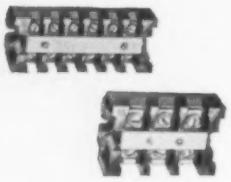
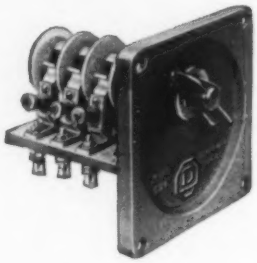
Limit Switches (Type C32L 810/1). Plunger pattern with roller on end. Roller can be moved through 90 degrees and the switch can be altered from N.O. to N.C. on site.



Terminal Blocks (Type J96). Clamp type terminals, White marker strip, generous clearances between phases and to earth. Sizes available—15-amp. 550-volt. 3, 4, and 6-way. 30-amp. 550-volt. 3 and 4-way.



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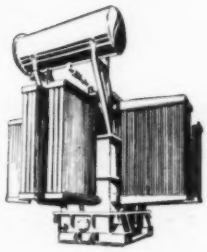

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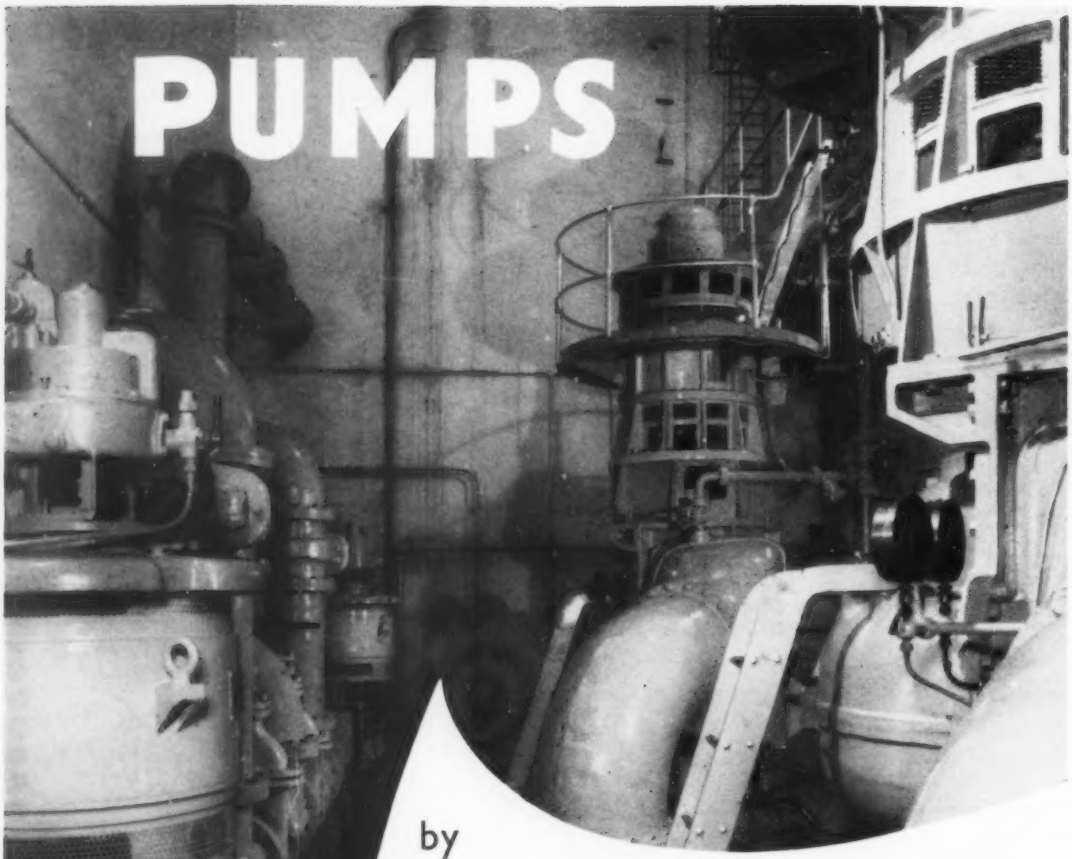

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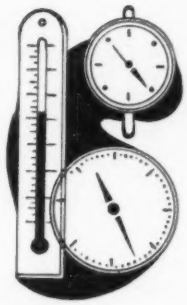

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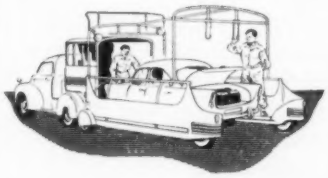

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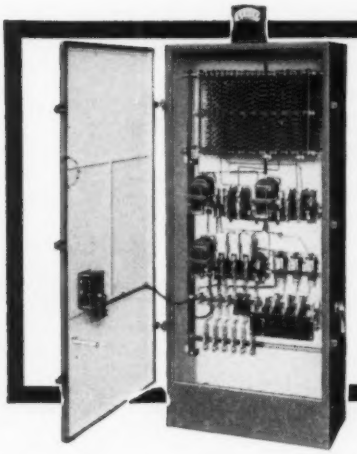

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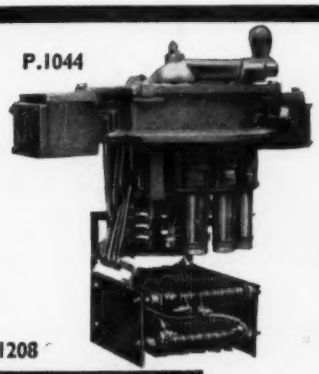

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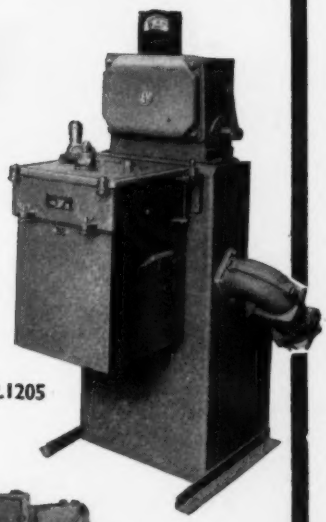

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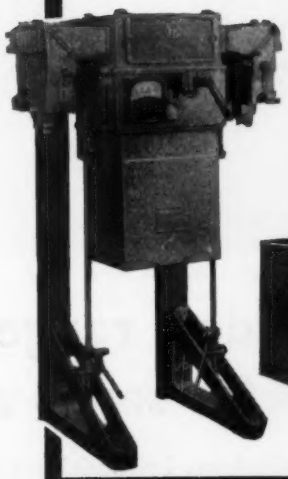

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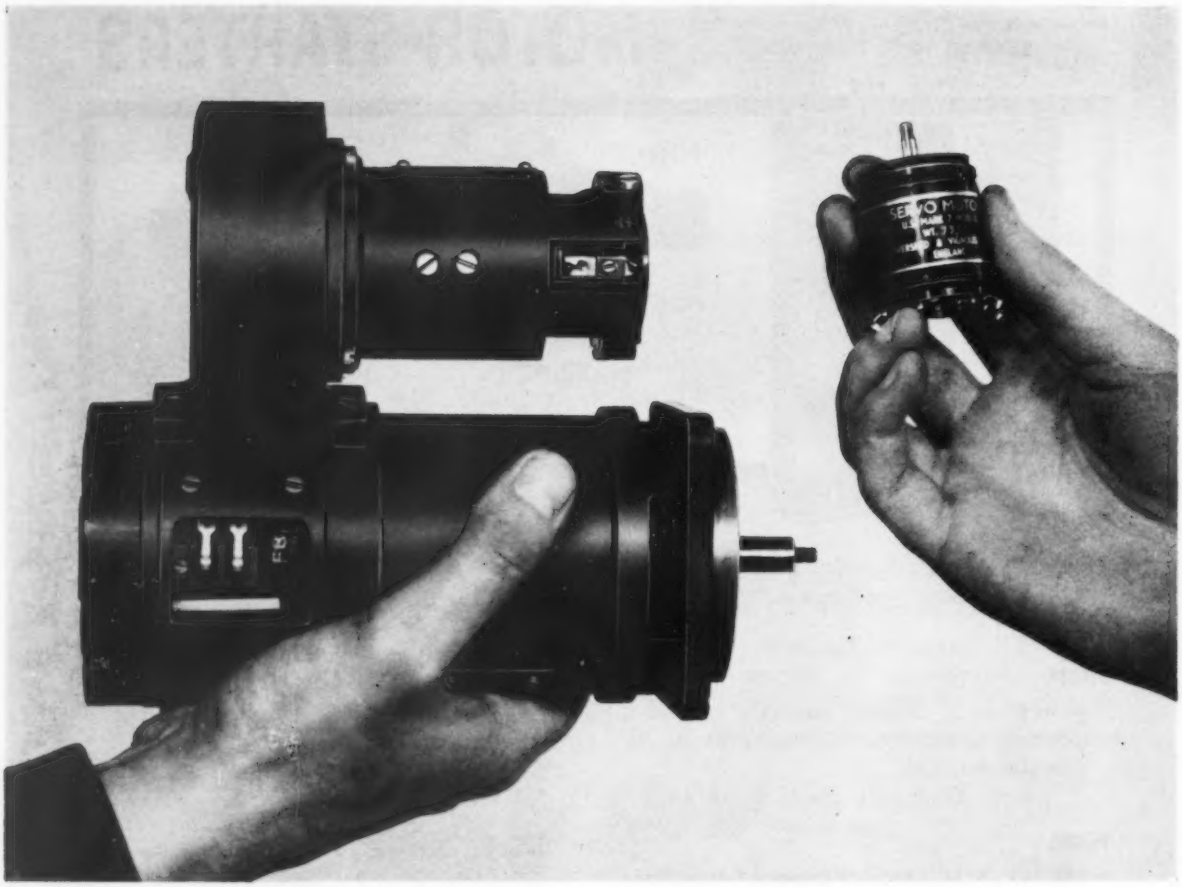

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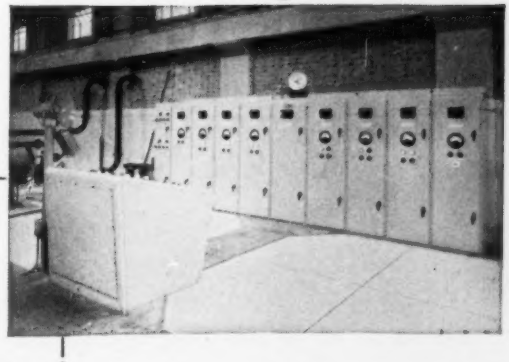

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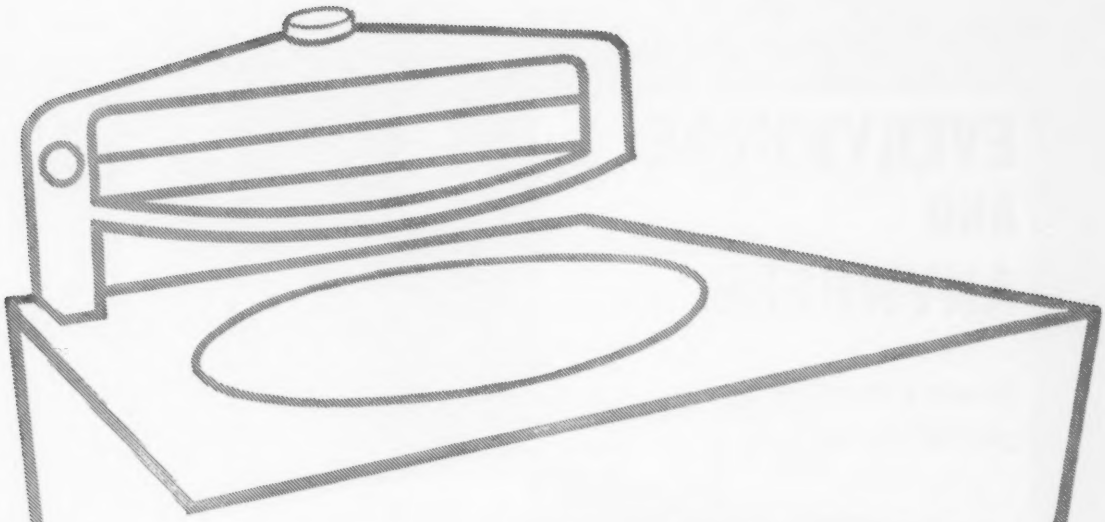

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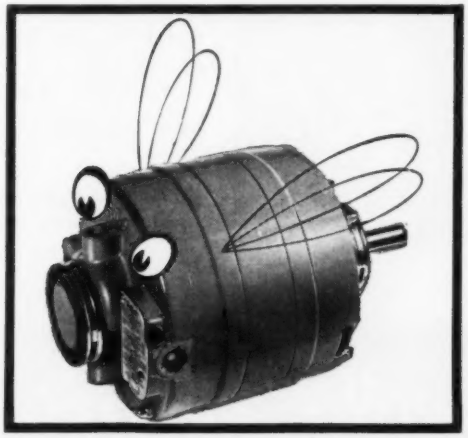

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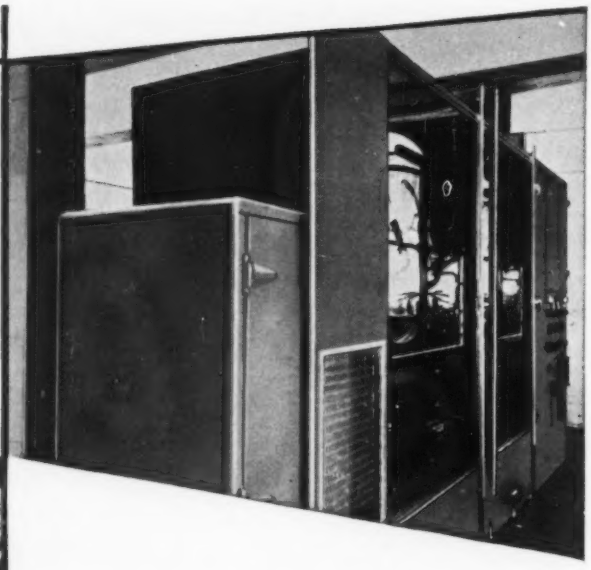

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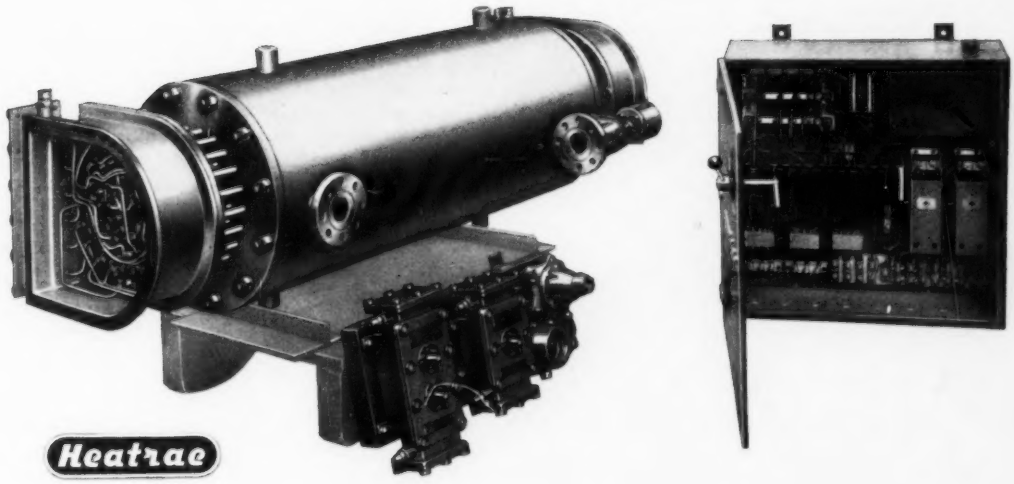

The illustration shows a 40 kW Air Heater and Control Panel. The heater works at a temperature of 1000° F at a pressure of 40 p.s.i. The terminal box is well away from the heat zone so that the temperature of the external connections is kept within safe limits. The high temperature necessitated a stainless steel construction.

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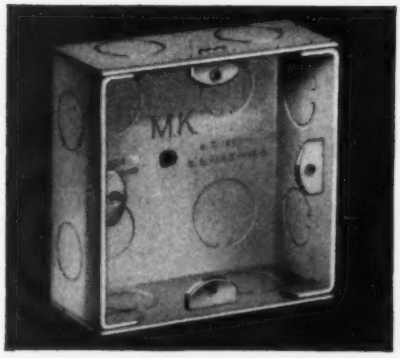

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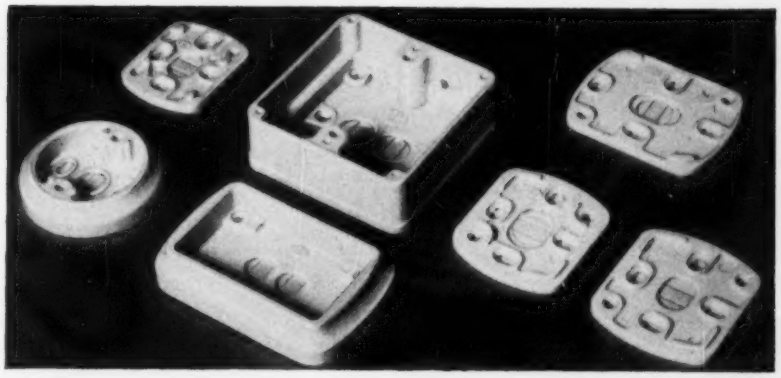

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NOW IN IVORY

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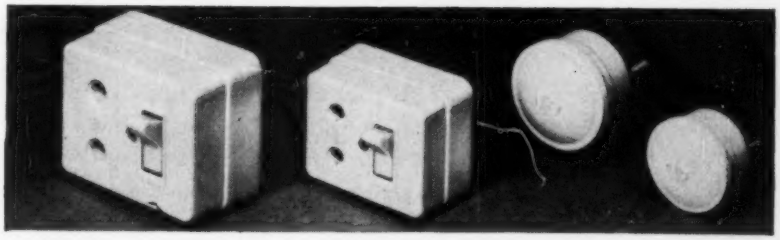

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Two of twelve boiler feed pumps installed in a C.E.G.B. generating station. They are arranged in six sets, each comprising a pump for 100% duty and a single 100% standby unit. Each pump is a 9"/11" Plurovane with a duty of 900,000 lb. of feed water per hour at 270°F and 1960 lb./sq. in. delivery pressure. The pumps are driven by Mather & Platt 3140 b.h.p. squirrel cage induction motors at 3000/2970 r.p.m. direct-on started taking 4½ times full load current. The motors are closed air circuit ventilated with water cooled air coolers.

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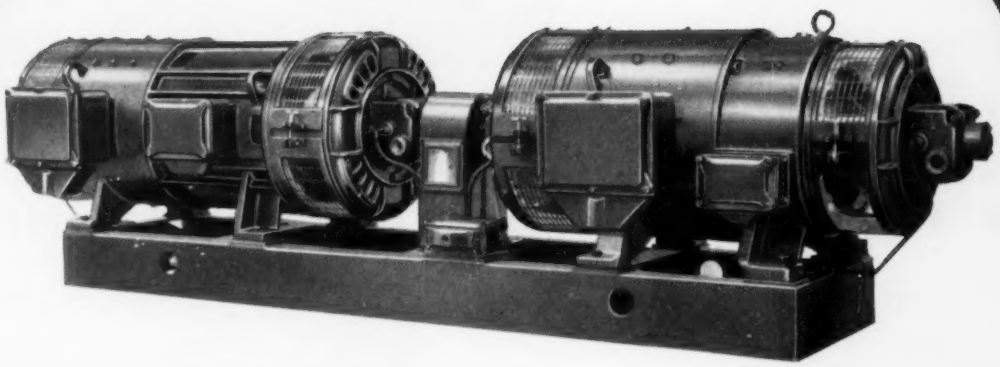

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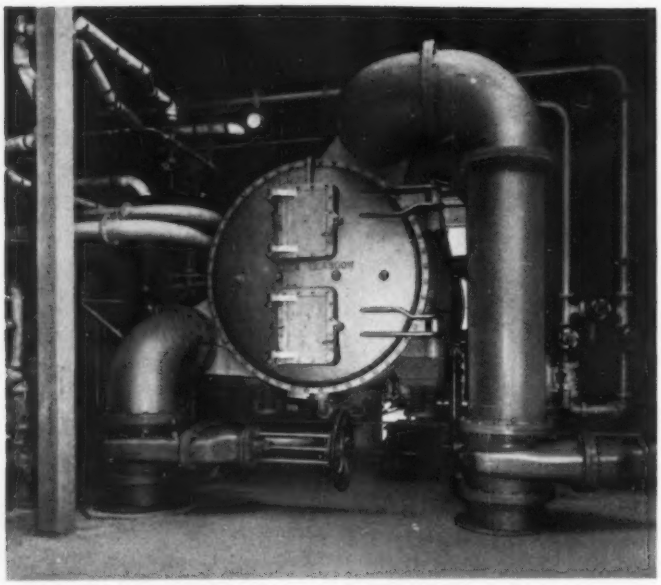
Surface Condensing Plant operating with a 10,000 Kw Turbo-Alternator Set.



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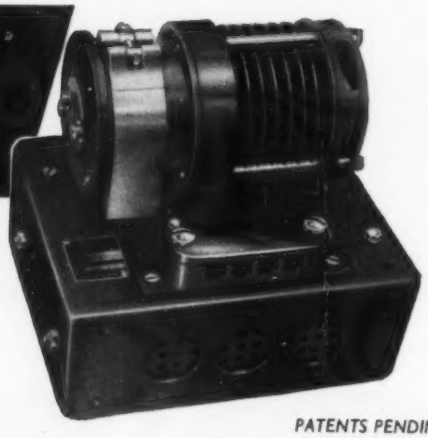
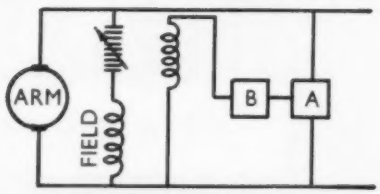


Model shown is for the control of a 28 Volt D.C. generator for use on aircraft.

PATENTS PENDING



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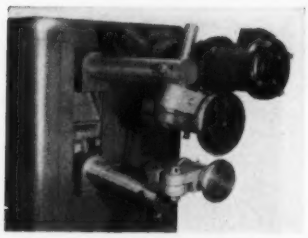

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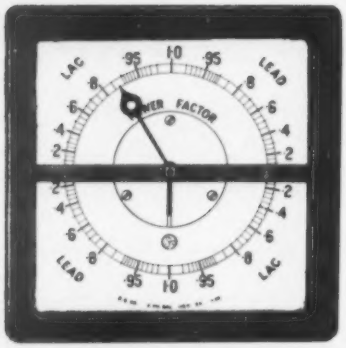

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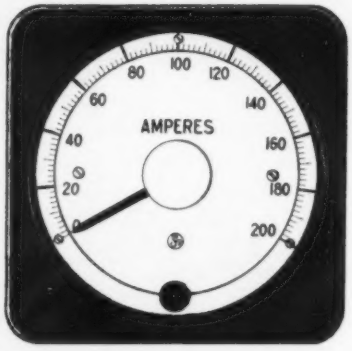

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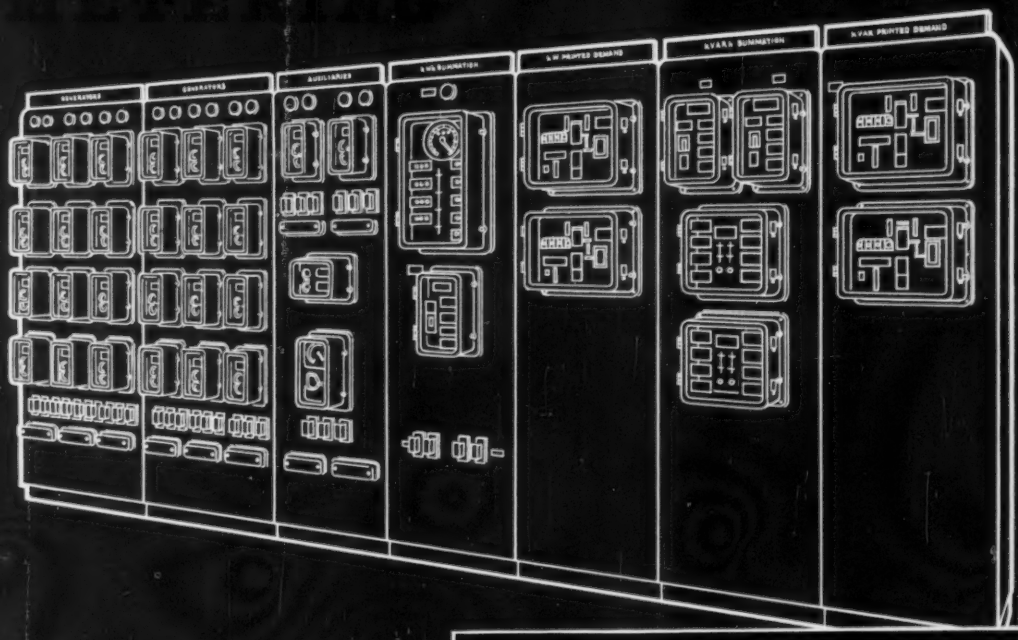
SUMMATION METERING



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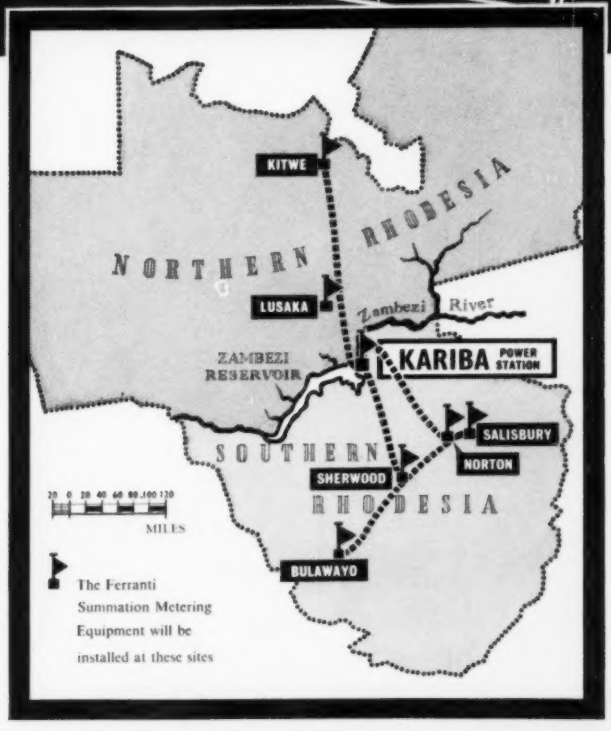
The Mechanical and Electrical Consulting Engineers for the Kariba project are Messrs. Merz & McLellan.



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